19930092945

MR Dec. 1943

L-550

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WARTIME REPORT

ORIGINALLY ISSUED
December 1943 as
Memorandum Report

FLIGHT TESTS OF BEVELED-TRAILING-EDGE AILERONS WITH VARIOUS MODIFICATIONS ON A NORTH AMERICAN XP-51 AIRPLANE (AAF No. 41-38)

By Maurice D. White and Herbert H. Hoover

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

WASHINGTON

L - 550

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

MEMORANDUM REPORT

for the

Army Air Forces, Materiel Command

FLIGHT TESTS OF BEVELED-TRAILING-EDGE AILERONS WITH VARIOUS MODIFICATIONS ON A NORTH AMERICAN XP-51 AIRPLANE

(AAF No. 41-38)

By Maurice D. White and Herbert H. Koover

SUMMARY

Flight tests have been conducted on a North American XP-51 airplane with several arrangements of beveled-trailing-edge ailerons to determine the most satisfactory arrangement for use on this airplane, The aileron control force and effectiveness characteristics were investfgated for average bevel angles of 25°, $27\frac{1}{2}°$, and 32°, and for several arrangements of balancing tabs, The test program included, in addition, the determination of a suitable means for trimming the beveled-trailing-edge ailerons.

The results indicate that, as the bevel angles were increased above 25°, the hinge-moment slopes were reduced at small control deflections, but were increased at large control deflections; as a result the variation of stick force with aileron deflection deviated progressively from the approximately linear relationship of the 25°-bevel-angle ailerons, particularly at high speeds. With a bevel angle of 32° the ailerons were overbalanced at indicated airspeeds above 200 miles per hour for aileron deflections below about ±7°.

The addition of sealed inset balancing tabs of chord equal to or greater than the bevel chord installed on the 25°-bevel-angle ailerons reduced the hinge moments without serious effect on the variations of stick force with aileron deflection. With an arrangement of balancing tabs of chord equal to the bevel chord on the 25°-bevel-angle ailerons, a value of $pb/2V$ of 0.095 was obtained at an indicated airspeed of 200 miles per

hour with full control deflectfon; with a 50-pound stick force, values cf $pb/2V$ of 0.086 and 0.041, respectively, were obtained at indicated airspeeds of 280 and 400 miles per hour.

Adequate trimming effectiveness was obtained with a sealed inset tab. Fixed external tabs were less effective and increased the aileron operating forces with the tabs either deflected or undeflected.

During the investigation, it was found that such factors as rnisalinement of the ailerons, location of an experimental airspeed boom on the wing ahead of an aileron, and other items tending to disturb the symmetry of boundary-layer flow over the two ailerons caused excessive trfm forces and differences in aileron operating forces required for right and left rolls.

INTRODUCTION

The results of previous NACA flight tests of the XP-51 airplane with beveled-trailing-edge ailerons having a trailing-edge angle of 25° showed that, with this modification, a marked improvement in lateral control characteristics was obtained as a result of a large reduction in aileron hinge moments. At the same time, however, it was found that an unsealed inset tab of a size which gave satisfactory trimming effects with the original cusp ailerons was inadequate for trimming the beveled-trailing-edge ailerons.

The present report gives the results of a more complete flight investigation to develop an arrangenent of beveled-trailing-edge ailerons that would provide further improvement in the control characteristics of the P-51 airplane.

Three bevel angles and several arrangements of balancing tabs were tested, The investigation also included tests to determine a suitable means for trimming the beveled-trailing-edge controls.

TEST ARRANGEMENTS

The wing of the XP-51 airplane has a span of 37.03 feet, an area of 235.75 square feet, and a taper ratio of 0.45. The wing is of the low-drag type with the point of minimum pressure at 0.4c and with a cusped trailing edge. The wing plan form is shown in figure 1.

In the course of the investigation, a large number of modifications were tested. The flight conditions comprising various combinations of these modifications are defined in table I; each flight condition has been assigned a letter as a convenient means of identification in presenting the test results.

The span of all the ailerons tested was $83\frac{5}{16}$ inches and the chord tapered from about 13 inches to $9\frac{1}{4}$ inches; the average ratio of aileron chord to wing chord was about 0.19.

Four aileron configurations, which have been designated 25°-, $27\frac{1}{2}^{\circ}$-, 32°-bevel-angle ailerons, and cusp ailerons were tested. The bevel angle is defined as the included angle at the trailing edge of the ailerons. As indicated in figure 2(a), where the sections at the inboard and outboard ends of the ailerons are shown, the designation for two of the beveled-trailing-edge ailerons refers to the average bevel angle along the aileron span. For the $27\frac{1}{2}^{\circ}$-bevel-angle ailerons, the bevel angle was uniform along the span. The cusp ailerons, with which the airplane was originally equipped, had concave surfaces conforming to the normal airfoil sections of the wing; unsealed balancing tabs were used on these ailerons for all tests. Sections of the cusp ailerons are shown in figure 2(b).

The $27\frac{1}{2}^{\circ}$- and 32°-bevel-angle ailerons were constructed by attaching wood false ribs to the original cusp ailerons; an aluminum covering was then fastened to the ribs with wood screws and riveted to the original covering along the leading edge (reference 1). The

25°-bevel-angle ailerons were fabricated similarly to the original cusp ailerons, that Is, with aluminum alloy ribs and covering (reference 2).

Some tests were made of the 32°-bevel-angle ailerons to determine the effects of sealing the nose gaps of the ailerons. The sealing was accomplished with doped fabric between the trailing edge of the fixed portion of the wing and the hinge axis of the aileron.

During the test program the available deflection range of the ailerons was changed several times with resultant changes in the mechanical advantage of the control system. The various relationships between aileron deflection and stick-grip position used are shown in figure 3, and in table I the particular control system linkage used for each flight is listed.

Two sets of inset balancing tabs, which have been designated normal-chord and large-chord balancing tabs, were tested on the 25°-bevel-angle ailerons. The nose gaps of both sets of tabs were sealed with doped fabric.

The normal-chord tabs had approximately the same plan-form dimensions as the balancing tabs on the original cusp ailerons. They were $24\frac{5}{16}$ inches in span (0.29 of the aileron span) and were tapered in chord from $4\frac{1}{4}$ Inches to $3\frac{3}{4}$ Inches (0.34 of the aileron chord) (figs. 1 and 4). These tabs were tested at linkage ratios of 0.61, 0.77, and 0.78, linkage ratio being defined as the ratio of tab deflection to aileron deflection.

The large-chord tabs had the same span as the normal-chord tabs, but were 1 inch greater in chord (0.39 of the total aileron chord.), the additional chord projecting behind the trailing edges of the ailerons (figs. 1, 4, and 5). These tabs were tested at a linkage ratio of 0.78.

During the tests of the inset balancing tabs, the tab on the left aileron was employed both as a trimming tab and as a balancing tab. Some tests were also made with a normal-chord inset tab installed only on the left aileron as a trimming tab.

Tests were conducted with a set of fixed external tabs on the 32°-bevel-angle ailerons. These tabs, which consisted of flat sheets of metal installed on the inboard end of each aileron, were 12 inches in span and $1\frac{5}{16}$ inches in chord (fig. 1). When these tabs were deflected to balance an existing trim force, the tab on the left aileron was deflected up and the tab on the right aileron was deflected down.

During the early tests of the investigation, it was found that rather large stick forces were required for lateral trim and that there were considerable differences in stick forces required for left and right rolls. Several possible causes of these conditions were investigated including aileron alinement and factors that might produce differences in the boundary layer over the two ailerons. A description of the factors investigated follows:

For some of the tests, an airspeed head was mounted on a boom fastened to the lower surface of the left wing ahead of the aileron (figs. 1 and 6). To determine the effect of this installation, tests were made with the boom removed.

The first tests of the present series were made with regulation star insignia painted on the upper surface of the left wing and on the lower surface of the right wing (fig. 1); the edges of these insignia were quite sharp and about 0.008 inch high. Later tests were made with the edges of the two Insignia sanded smooth, no changes being made to the remaining surfaces which were covered with camouflage paint.

Some tests were made with spanwise strips fastened to the wing surfaces ahead of the ailerons in an effort to cause transition of the boundary layer at the same point on both left and right wings. These strips consisted of lengths of double-thickness fabric doped to the wing surface (fig. 1). On the lower surfaces, the strips were located about $7\frac{1}{2}$ percent of the chord, measured along the surface, aft of the leading edge and were 0.018 inch thick and 1 inch wide. On the upper surfaces the strips were located about 10 percent of the chord, measured along the surface, aft of the leading edge and

were 0.018 inch thick and $\frac{1}{2}$ inch wide. The strips were always located symmetrically, either on the lower surfaces of both left and right wings, or on both the upper and lower surfaces of both left and right wings.

For most of the tests of the various aileron arrangements, the left aileron was out of alinement vertically with respect to the wing due to the location of the hinge fittings in the wing (fig, 7). To investigate the effect of this misalinement, tests were made with wooden wedges approximately half the aileron span in length, $1\frac{3}{4}$ inches wide, and tapered in height from $\frac{1}{8}$ inch to a feather edge, located spanwise on the wing directly ahead of the outboard halves of the ailerons to simulate or to fair in the misalinement (fig. 1). One wedge was installed on the lower surface of the right wing to simulate the misalinement of the left aileron; the other wedge was installed on the upper surface of the left to fair in the misalinement. For several of the tests with the 25°- and $27\frac{1}{2}^{\circ}$-bevel-angle ailerons the alinement was corrected by lowering the outboard end of the aileron $\frac{9}{64}$ inch, with the inboard end unchanged (fig. 7). The hinge axis remained unchanged.

TESTS

The procedure used for the tests was similar to that used in the tests of references 1 and 2; that is, records were obtained of airspeed, aileron deflections, stick force, and rate of roll as the aileron control was abruptly deflected various amounts and held, the other controls being held Fixed.

Standard NACA recording instruments were used. These included a stick-force recorder, control-position recorders connected to both ailerons, and an airspeed recorder. The airspeed recorder was connected to the NACA airspeed head when this was available; otherwise, it was connected to the airplane airspeed head. Flight calibrations were obtained for both these heads. For several flights, noted in table 11, an airspeed indicator was used instead of the recorder.

The majority of the tests were made over a range of indicated airspeeds from about 110 miles per hour to about 300 miles per hour. With the cusp ailerons and for sone tests of the 25°-bevel-angle ailerons, the speed range was extended to about 440 miles per hour. Because the $27\frac{1}{2}^{\circ}$- and the 32°-bevel-angle ailerons were considerably heavier in weight than the original cusp ailerons and it was uncertain what effect this increased weight would have on the flutter characteristics of the wing, the tests of these ailerons were restricted to indicated airspeeds below approximately 300 miles per hour. The indicated airspeeds of the tests of each of the arrangements listed in table I are given in table II.

RESULTS AND DISCUSSION

The results of the tests are shown in figures 8 to 29, the data being presented largely in the form of curves of aileron stick force and the effectiveness parameter $pb/2V$ against change in total aileron deflection from trim for several indicated airspeeds. The parameter $pb/2V$ is defined by

P angular velocity in roll, radians per second

b wing span, feet

V true airspeed, feet per second

The average indicated airspeed for each group of curves 4s indicated on the figures.

Indicated airspeed, as used throughout this report, is defined as $V_i = 0.681\sqrt{\frac{2q}{\rho_o}}$

where

V_i indicated airspeed, miles per hour

q dynamic pressure, pounds per square foot

sea-level density, slugs per cubic foot

The values obtained from this definition differ somewhat from the values given En references 1 and 2 where indicated airspeed was defined as

$$V_i = 0.681 \sqrt{\frac{2q_c}{\rho_o}}, \quad q_c \text{ being the impact pressure.}$$

To serve as a basis for Comparison, the results for condition P are repeated in all the curves. Condition P represents the 25°-bevel-angle ailerons with the air-speed boom removed, the insignia smoothed, and no transition strips on the wing.

Aileron Configuration

The results of tests of various aileron arrangements intended to give improved stick-force and effectiveness characteristics are shown in figures 8 to 18.

Bevel angle.- In figures 8 and 9 the characteristics of the 32°-bevel-angle ailerons are shown, The data in figure 8 snow that these aflerons are unsatisfactory because they become overbalanced for small control deflections at normal fifght speeds.

The data shown in figure 10 afford a comparison of the stick-force characteristics of the 25°- and the $27\frac{1}{2}^\circ$-bevel-angle ailerons. The results indicate that, in general, the ailerons having the 25° bevel angle are superior to those having the $27\frac{1}{2}^\circ$ bevel angle, The stick forces for the 25°-bevel-angle ailerons are higher at small control deflections, but are, on the average, equal to or lower at the larger control deflection than those for the $27\frac{1}{2}^\circ$-bevel-angle ailerons. Also, the variation of stick force with aileron deflection is more nearly linear for the 25°-bevel-angle ailerons than for the $27\frac{1}{2}^\circ$-bevel-angle ailerons with the control linkage used. Greater sensitivity of stick-force characteristics to changes in aileron alinement for the $27\frac{1}{2}^\circ$-bevel-angle ailerons as compared with the 25°-bevel-angle ailerons is indicated in figure 10.

A comparison of the data in figures 8 and 10 with 9 and 11 fndicates that bevel-angle modifications that reduce the stick forces also tend to reduce the effectiveness. As a consequence the effectiveness of the

32'-bevel-angle ailerons is less than that of the 25° and the $27\frac{1}{2}^\circ$-bevel-angle ailerons.

Sealed aileron nose gaps.- During the tests of the 32°-bevel-angle ailerons, the effects of sealing the nose gaps of the ailerons were investigated. The results presented in figure 12 indicate that this modification effectively reduced, but did not entirely eliminate the overbalance noted at small control deflections, Qualitatively, this result is in agreement with wind-tunnel results (reference 3).

The data in figure 13 indicate that the aileron effectiveness, as defined by the slope of the curve of $pb/2V$ against aileron deflection, is increased slightly by sealing the nose gags of the ailerons.

An interesting free-control oscillation of the ailerons was recorded at an indicated airspeed of approximately 320 miles per hour for the sealed-gap condition when the control stick was released. A time history of this oscillation showing aileron position, airspeed, and rolling velocity is given in figure 14.

The pilot was unable to induce similar oscillations at lower speeds.

Balancing tabs.- Previous tests having indicated the 25°-bevel-angle contour to be the most satisfactory of the three contours tested, tests of sealed balancing tabs, designed to improve still further the stick-force characteristics of these ailerons, were made only with the 25°-bevel-angle ailerons,

The stick-force characteristics of 25°-bevel-angle ailerons with normal-chord tabs and large-chord tabs, each set operating at a linkage ratio of about 0.78, are compared in figure 15; data are also given for the normal-chord tabs operating at a linkage ratio of 0.61. In these tests, the tab was not used for trimming. With both tab-linkage ratios the normal-chord. balancing tabs effected a marked reduction in stick forces as compared with the ailerons with no tabs. The magnitude of the hinge-moment reduction is even greater than would be indicated by a simple comparison of the stick forces because, simultaneously with the installation of the balancing tabs, the deflection range of the ailerons was increased for the same stick travel, thereby reducing the mechanical advantage of the control system.

A further decrease in stick forces was accomplished by increasing the chord of tne balancing tabs, the additional chord projecting behind the aileron trailing edge.

As shown in figure 16, the effectiveness per unit control deflection was reduced by the addition of balancing tabs, the average reduction being about the same for all tab arrangements. An item of additional interest shown in figure 16 is the tendency of the large-chord' balancing tabs to eliminate an asymmetry in effectiveness slopes between right and left rolls experienced. with the normal-chord tabs,

Effectiveness of principal modifications.- In order to provide a comparison of the improvement in characteristics effected by the principal modifications, data for the cusp ailerons and the 25°-bevel-angle ailerons with balancing tabs and the 25°-bevel-angle ailerons without balancing tabs are presented in figures 17, 18, and 19. The balancing tabs on both sets of ailerons were the size designated as normal-chord tabs. In figures 17 and 18, the stick-force and effectiveness characteristics are plotted against control deflectfon, and in figure 19 the values of $pb/2V$ obtainable with a 30-pound stick force and a 50-pound stick force are shown plotted against indicated airspeed for each installation, In some cases it was necessary to extrapolate the data of figures 17 and 18 to full deflection or to a stick force of 50 pounds, as indicated by the dotted extensions to the curves, in order to permit construction of the curves of figure 19. It should be noted that the mechanical advantage of the aileron control system used in obtaining the data shoun in these figures for the 25°-bevel-angle ailerons was greater than that used in obtaining the data of figures 15 and 16 with the result that lower stick forces were obtained for a given condition. Inasmuch as known sources of disymmetry discussed in a later Section of this report were eliminated, the causes of differences in stfck-force characteristics between right and left rolls, evident in figure 17, are not known.

The data of figure 19 indicate that, with beveled trailing-edge ailerons and normal-chord balancing tabs, a value of $pb/2V$ of about 0.095 was obtained at an Indicated airspeed of 200 miles per hour with full control deflection. With a stick force of 50 pounds, values of $pb/2V$ of 0.086 and 0.041 were obtained at

indicated airspeeds of 280 and 400 miles per hour, respectively. These values represent increases in rate of roll of 100 percent at 280 miles per hour and 37 percent at 400 miles per hour over that obtained with the cusp aileron-balancing tab arrangement.

Some minor differences are evident between the data for the cusp ailerons and the 25°-bevel-angle ailerons presented in this report and the data presented in references 1 and 2. This is probably due to the fact that, because of manufacturing irregularities, neither of the sets of ailerons tested here was identical with those previously tested,

Trimming Tabs

Several arrangements of tabs were investigated to determine a suitable means for trimming the beveled trailing-edge ailerons. The results of these tests are indicated in figures 20 through 23,

Inset tabs.- In figure 20 the trim-force variation with airspeed for several deflections of a normal-chord tab is shown. With a sealed inset tab installed on the left aileron only (fig. 20(c)), substantial changes in trim force were obtained by deflecting the tab. The available tab deflection range of ±7° was insufficient, however, to trim out the forces caused by the installation of an NACA airspeed boom on one wing.

With sealed inset balancing tabs on both ailerons, and with wing conditions symmetrical except for the misalinement of the left aileron, the tab on the left aileron provided complete trim as Indicated in figure 20(b).

An observation pertinent to the present discussion was made when a very pebbly coating of paint was inadvertently applied on the upper surface of the right wing, It was found that, all other conditions corresponding to those of figure 20(b), a tab deflection of approximately 8° was then required for trim. This result is of interest as an indication of the trimming tab deflection range that should be provided with the beveled trailing-edge ailerons.

As a matter of interest, data from reference 2, showing the relative characteristics of completely sealed and imperfectly sealed tabs, are shown in figure 20(a). These data indicate that the imperfectly sealed tab itself introduces asymmetry such that

approximately 7° of deflection is required! of the tab to trim out its own effect,

The actual trimming effectiveness was not investigated for the sealed large-chord tabs, but the data for these tabs in figure 15 indicate their effectiveness as a trim tab would be about the same as that of the normal-chord tabs.

In connection with the use of deflected inset tabs for trim, the stick-force characteristics in rolls are of Interest. As shown by the data for 201 miles per hour in figure 22 and in reference 2, deflectfng an inset tab increases the stick forces in rolls to one side and reduces the stick forces In rolls to the other side. The direction of the effect corresponds to a persfstence of the trim-force change, but the magnitude of the force change appears to increase with increasing aileron deflee·tion. This behavior is in agreement with wind-tunnel data (reference 3).

Fixed external tabs. - The results shown in figure 21 for tests of fixed external tabs on the 32°-bevel-angle ailerons indicate that some trimming effect can be obtained with the fixed external tabs. Their practical value Is, however, diminished by the fact that, either deflected or undeflected, these tabs cause a considerable increase in stick force fn rolls (fig. 22). These results are in agreement with wind-tunnel data (reference 3).

The aileron effectiveness data in figure 23 indicate no difference in effectiveness characteristics to be caused by the fixed external tabs.

Factors Affecting Symmetry of

Aileron Characteristics

Reference to the test results previously discussed indicates that excessive trim forces and a difference between the stick forces required in right and left roll existed. In order to determine and eliminate the cause of these variations, the effects of several factors which included the NACA airspeed boom, the wing insignia, transition strips fastened to the leading edge of the wing surface, and vertical alinement of the aileron were investigated. Results of tests of these items are shown in figures 10 and 11 and 24 through 29.

The results shown by the test data may be summarized as follows:

Trim forces.- All the factors investigated had some effect on the asymmetric forces experienced, The principal source of the excessive trim forces, however, was the NACA airspeed boom as shown in figure 24. The transition strips which were always installed symmetrically reduced slightly the trfm forces caused by the airspeed. boom, Figure 28 shows the effect of the roughness caused by the wing insignia on the trim force. The rough edges of the wing insignia tended. to counteract the effects of the boom as shown by the fact that smoothing the edges of the insignia increased the forces requfred for trim with the airspeed boom in place. These insignia, it will be noted, were located unsymmetrically, one of the insignia being on the wing surface opposite that to which the airspeed boom was attached.

Figure 10 shows that the effect of aileron realinement on trim forces was rather large, particularly with the $27\frac{1}{2}^{\circ}$-bevel-angle ailerons. This trim-force change is in qualitative agreement wfth the effects of cover-plate realinement indicated in reference 3. The pilot's observations of the effects of alinement changes simulated by wedges indicated that these modifications were relatively ineffective as compared with actual realinement of the aileron.

Symmetry of forces In rolls.- As regards the asymmetry of force variations in rolls, the data in figures 24 and 28 indicate that the effects produced by the airspeed boom and wing insignia are, with the exceptions noted, consistent and explainable on the basis of premature separation over the aileron bulge, caused by the boom or the Insignia. In rolls in the direction of the trim-force change (that is, in right rolls where the modification required more right trim force) the forses obtained with and without the modification approached each other at large control deflections, In rolls to the opposite direction, the difference in trim force was maintained at all control deflectidns. Exceptions to this behavior were noted in left rolls at moderate speeds between the conditions of rough and smooth wing fnsignia.

Transition strips installed symmetrically, In general, reduced the forces in rolls for both the 25°- and the $27\frac{1}{2}^{\circ}$-bevel-angle ailerons (figs. 24 and 26).

Transition strips on only the lower surfaces gave about the same effect as strips on both upper and lower surfaces (fig, 24).

The effects of aileron misalinement on forces in rolls were different for the two aileron arrangements tested, With the 25°-bevel-angle ailerons, the difference in trim force was maintained at all control deflections, while with the $27\frac{1}{2}^{\circ}$-bevel-angle ailerons, the forces in rolls to both directions were less for the realined ailerons than they had been for the original alinement at large deflections,

Effectiveness.- As shown in figures 11, 25, 27, and 29 the various modifications discussed in this section of the report resulted in differences in effectiveness characteristics that were consistent with the stick-force changes; that is, lower effectiveness was generally associated with lower stick forces.

CONCLUSIONS

The results of flight tests of beveled trailing-edge ailerons with various modifications on a North American XP-51 airplane may be summarized as follows:

1. The 25°-bevel-angle ailerons gave a large reduction in hinge moments as compared to the original cusp aileron-balancing tab arrangement, and gave an approximately linear variation of stick force with aileron deflection for the control linkage used, Increasing the bevel angle above 25° caused greater reductions In hinge-moment slopes at small deflections, but increased the hinge-moment slopes at large deflections, so that the variation of stick force with aileron deflection departed increasingly from a linear relationship, particularly at high speeds. With a bevel angle of 32°, the ailerons were overbalanced at indicated airspeeds above 200 miles per hour for aileron deflections below about ±7°.

2. Further reductions in hinge moments were obtained with sealed inset balancing tabs of chord equal to or larger than the bevel chord installed on the 25°-bevel-angle ailerons.

3. The 25°-bevel-angle ailerons with sealed inset balancing tabs of span equal to 0.29 of the aileron span and chord equal to the bevel chord, geared to a linkage ratio of 0.78 to 1, gave a value of $pb/2V$ of 0.095 for full control deflection at an indicated airspeed of 200 miles per hour; with a 50-pound stick force, values of $pb/2V$ of 0.086 and 0.041 were obtained at indicated airspeeds of 280 and 400 miles per hour, respectively. These values represent increases in rate of roll of 100 percent and 37 percent at 280 and 400 miles per hour, respectively, as compared with the original cusp ailerons with balancing tabs.

4. A sealed inset tab gave adequate trimming effect and appears to be a satisfactory device for trimming beveled-trailing-edge controls. Fixed external trimming tabs were less effective and increased the stick forces in rolls whether the tabs were deflected or undeflected.

5. An asymmetry in stick-force characteristics for the beveled-trailing-edge ailerons, evidenced as excessive trim forces and as differences between the stick forces required in right and left rolls, was found to be due to several factors. These factors included misalinement of the ailerons, location of an experimental airspeed boom on the wing ahead of an aileron, and other items tending to disturb the symmetry of boundary-layer flow over the two ailerons.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., December 7, 1943.

REFERENCES

1. White, M. D., and Hoover, Herbert H.: Flight Tests of Modifications to Improve the Aileron Control Characteristics of a North American XP-51 Airplane (A.C. No, 41-38). NACA MR, June 20, 1942.

2. Hoover, Herbert H, and White, Maurice D.: Lateral-Control Characteristics of North American XP-51 Airplane (A.C. No. 41-38) with Beveled Trailing-Edge Ailerons in High-Speed Flight, NACA MR, Now. 27, 1942.

3. Rogallo, F. M., and Crandall, Stewart M.: Wind-Tunnel Investigation of Trimming Tabs on a Thickened and Beveled Aileron on a Tapered Low-Drag Wing. NACA A.C.R., March 1943.

TABLE I

SUMMARY OF FLIGHT TEST CONDITIONS

Figure number	Condition	Bevel angle deg	Aileron gap	Tab	Tab gap	Tab angle, deg	Wing surface conditions		Airspeed boom	Aileron Alignment	Control Linkage (See figure 3)
							Insignia	Transition strips			
8,9,22,23	A	32	Open	None	None	None	Rough	None	On	Original	II
12,13,21,22,23	B	32	Open	Fixed tab on each aileron	Sealed	0	Rough	None	On	Original	II
12,13	C	32	Sealed	Fixed tab on each aileron	Sealed	0	Rough	None	On	Original	II
12,13,14	D	32	Sealed	Fixed tab on each aileron	Sealed	± 7¼	Rough	None	On	Original	II
12,13,21,22,23	E	32	Open	Fixed tab on each aileron	Sealed	± 7¼	Rough	None	On	Original	II
20,22,23	F	25	Open	Inset trim tab on left aileron	Sealed	Variable	Rough	None	On	Original	II
	G	25	Open	Inset trim tab on left aileron	Sealed	Variable	Rough	None	On	Wedge ahead of right aileron.	I
	H	25	Open	Inset trim tab on left aileron	Sealed	Variable	Rough	None	On	Wedges ahead of both ailerons	I
28,29	I	27½	Open	None	None	None	Rough	None	On	Original	II
24,25,28,29	J	27½	Open	None	None	None	Smooth	None	On	Original	II
24,25	K		Open	None	None	None	Smooth	Strips ahead of both ailerons on lower surface	On	Original	II
24,25	L	27½	Open	None	None	None	Smooth	Strips ahead of both ailerons on upper and lower surfaces	On	Original	II
24,25	M	27½	Open	None	None	None	Smooth	Strips ahead of both ailerons on upper and lower surfaces	Off	Original	II
24,25	N	27½	Open	None	None	None	Smooth	Strips ahead of both ailerons on lower surface	Off	Original	II
10,11,24,25	O	27½	Open	None	None	None	Smooth	None	Off	Original	II
8 to 29	P	25	Open	None	None	None	Smooth	None	Off	Original	II
10,11	Q	25	Open	None	None	None	Smooth	None	Off	Left aileron realigned (see figure 7)	II
10,11	R	27½	Open	None	None	None	Smooth	None	Off	Left aileron realigned	II
15,16,20	S	25	Open	Balancing tab on each aileron	Sealed	Linkage ratio 0.61	Smooth	None	Off	Original	II
15,16	T	25	Open	Balancing tab on each aileron	Sealed	Linkage ratio 0.77	Smooth	None	Off	Original	II
17,18,19	U	Cusped	Open	Balancing tab on each aileron	Open	Linkage ratio 0.48	Smooth	None	Off	Original	I
15,16	V	25	Open	Large chord balancing tab on each aileron	Sealed	Linkage ratio 0.78	Smooth	None	Off	Original	I
26,27	W	25	Open	Balancing tab on each aileron	Sealed	Linkage ratio 0.78	Smooth	Strips ahead of both ailerons on upper and lower surfaces	Off	Original	
17,18,19,26,27	X	25	Open	Balancing tab on each aileron	Sealed	Linkage ratio 0.78	Smooth	None	Off	Original	

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

L-550

TABLE II

SUMMARY OF AVERAGE TEST AIRSPEEDS

Condition	Average indicated airspeeds, miles per hour $V_i = 0.681\sqrt{\frac{2q}{\rho_0}}$							
A	107	153	200	251				
B	117	153	202	251	296			
C	116	157	204	252	296			
D	115	154	204	250	296			
E	115	153	202	250	297			
F			202	251	298			
I	114	153	201	250	297			
S	115	153	206	252	294			
K	109	149	198	248	294			
L	112	152	202	250	297			
M [1]	112	152	202	250	296			
N [1]	112	152	202	250	296			
O [1]	112	152	202	250	296			
P	113	151	201	249	299			
Q	115	151	202	249	298			
R	113	151	202	249	299			
S	112	151	201	249	300	343	392	437
T	114	150	201	250	300	344	394	438
U	114	149	202	249	301	345	394	438
V	113	149	202	248	296			
W	112	150	200	244	295	346	385	433
X			196	245	303	340	379	430

1. Airspeeds for conditions M, N, and O were obtained from readings of pilot's indicator instead of recorder.

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

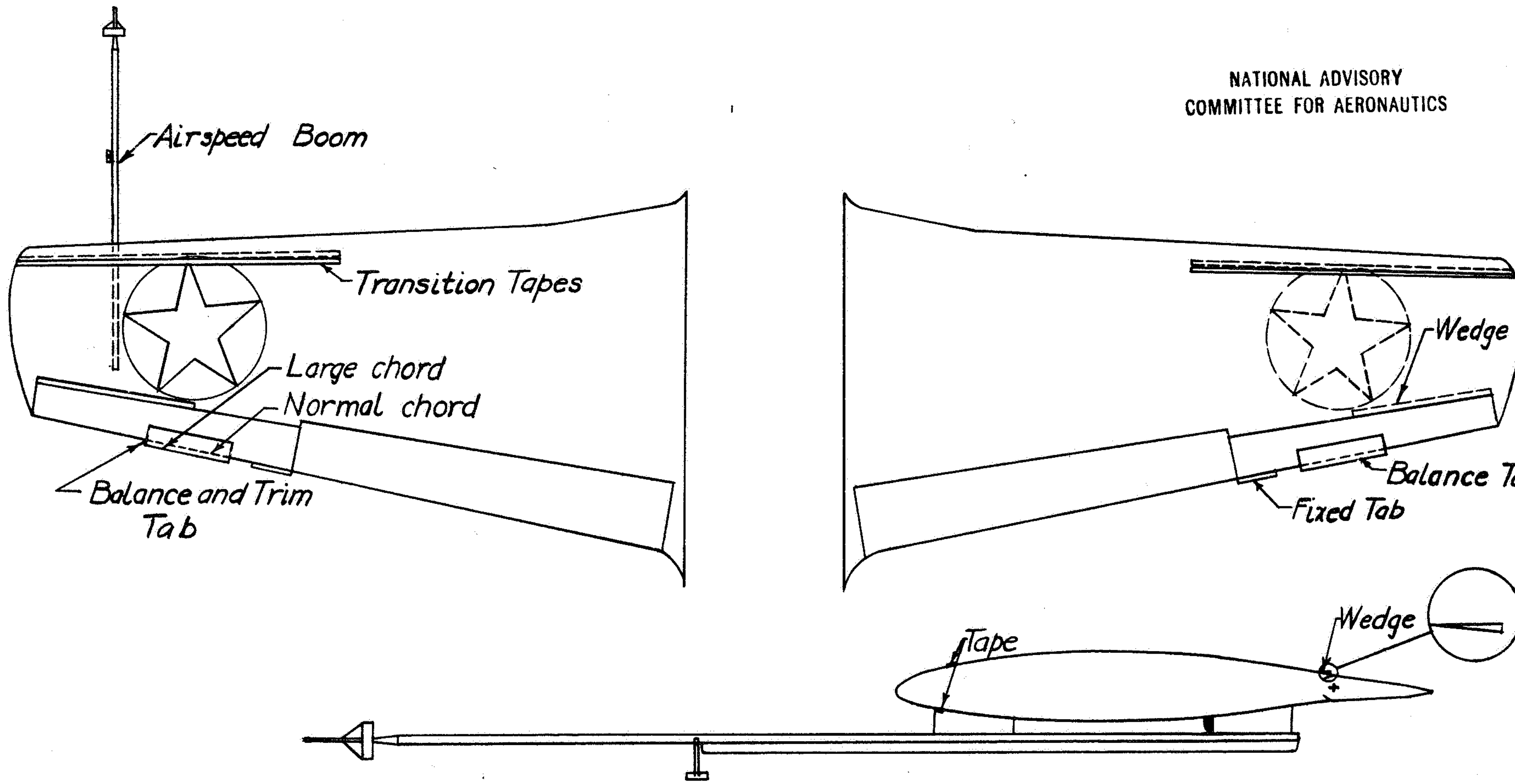


Figure 1.- XP-51 wing showing modifications

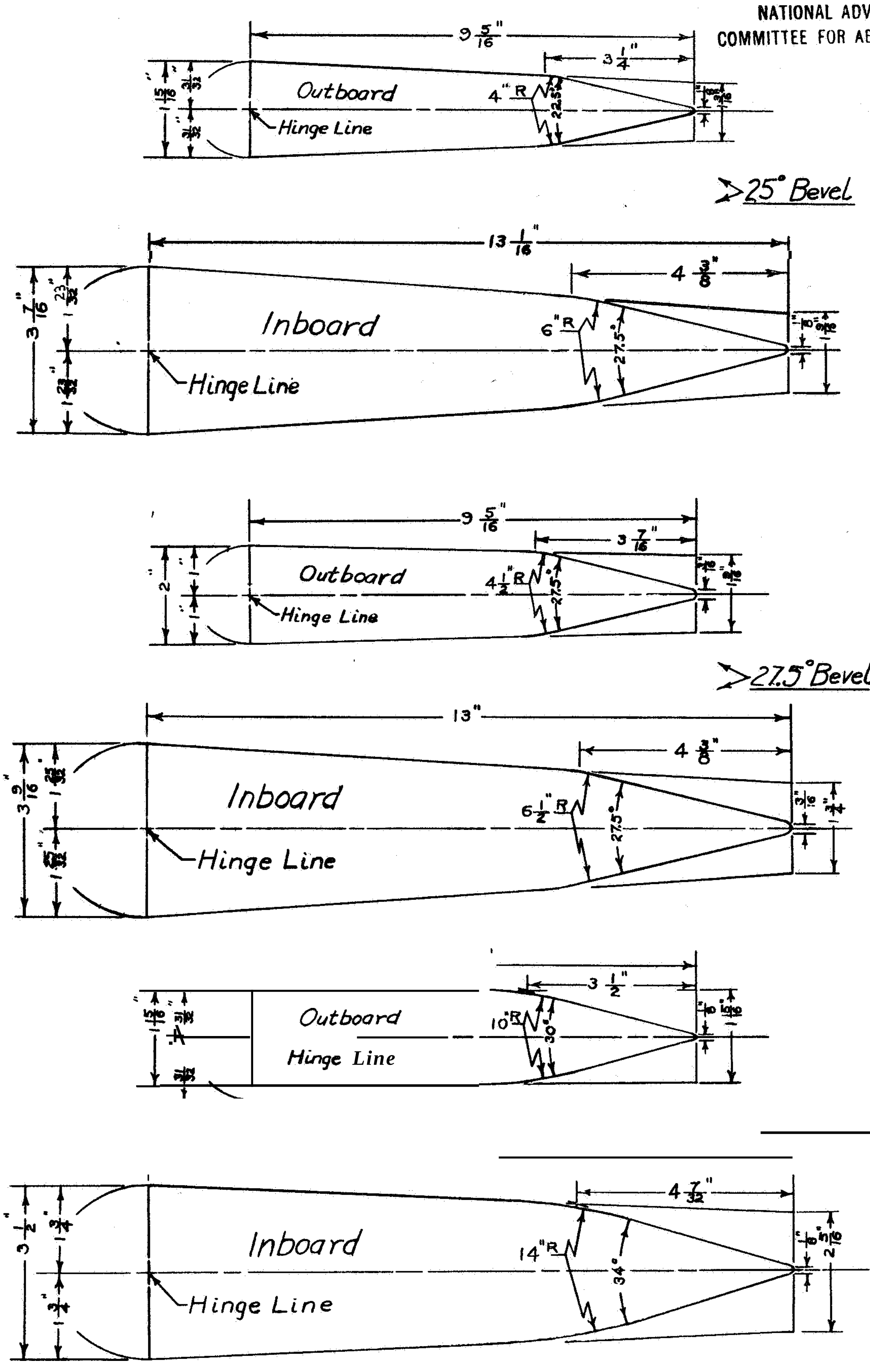
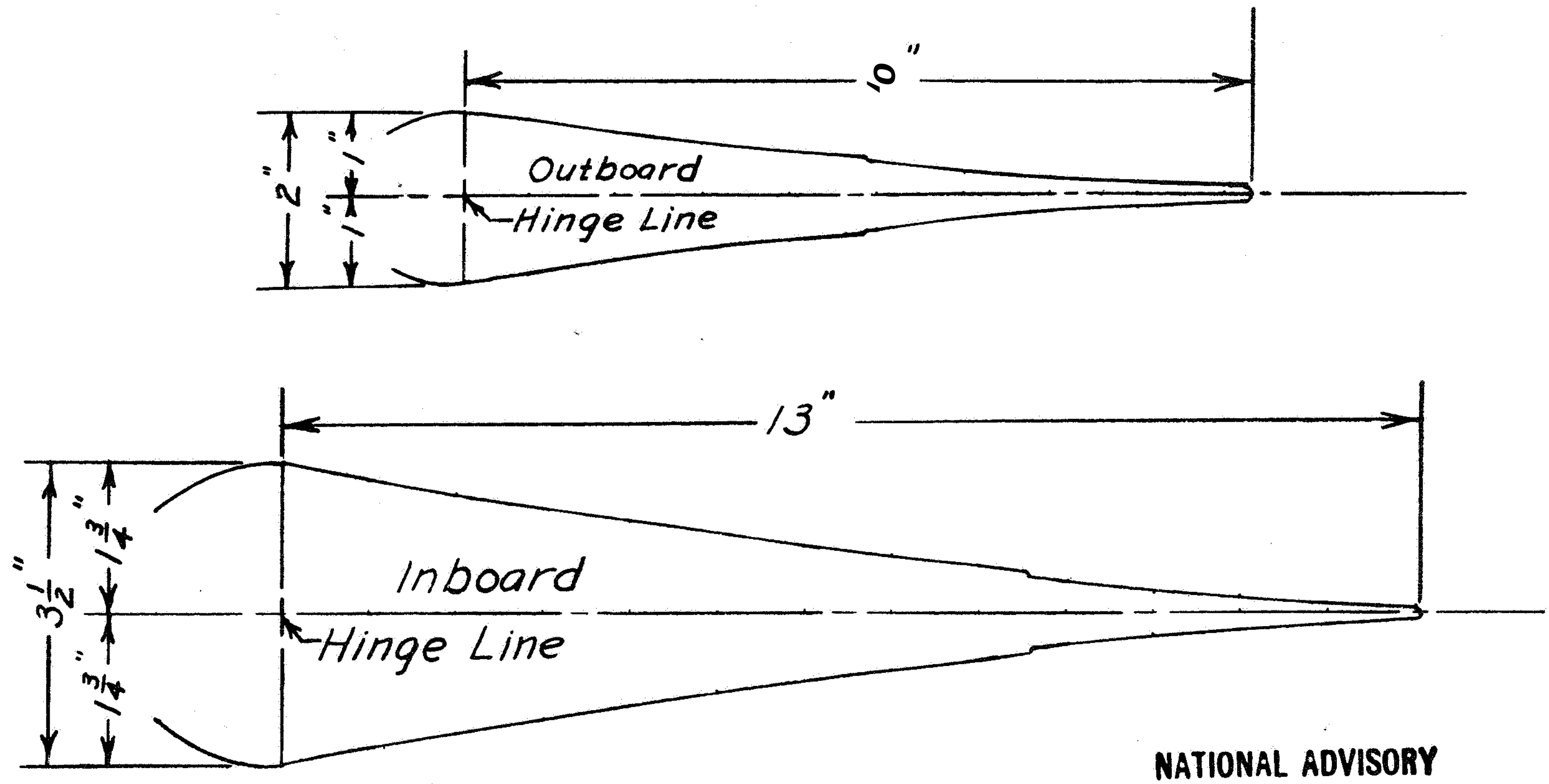


Figure 2a.- End sections of beveled **trailing-edge** *ailerons. XP-51 airplane.*



NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

Figure 2b.-End sections of cusp ailerons. XP-51 airplane.

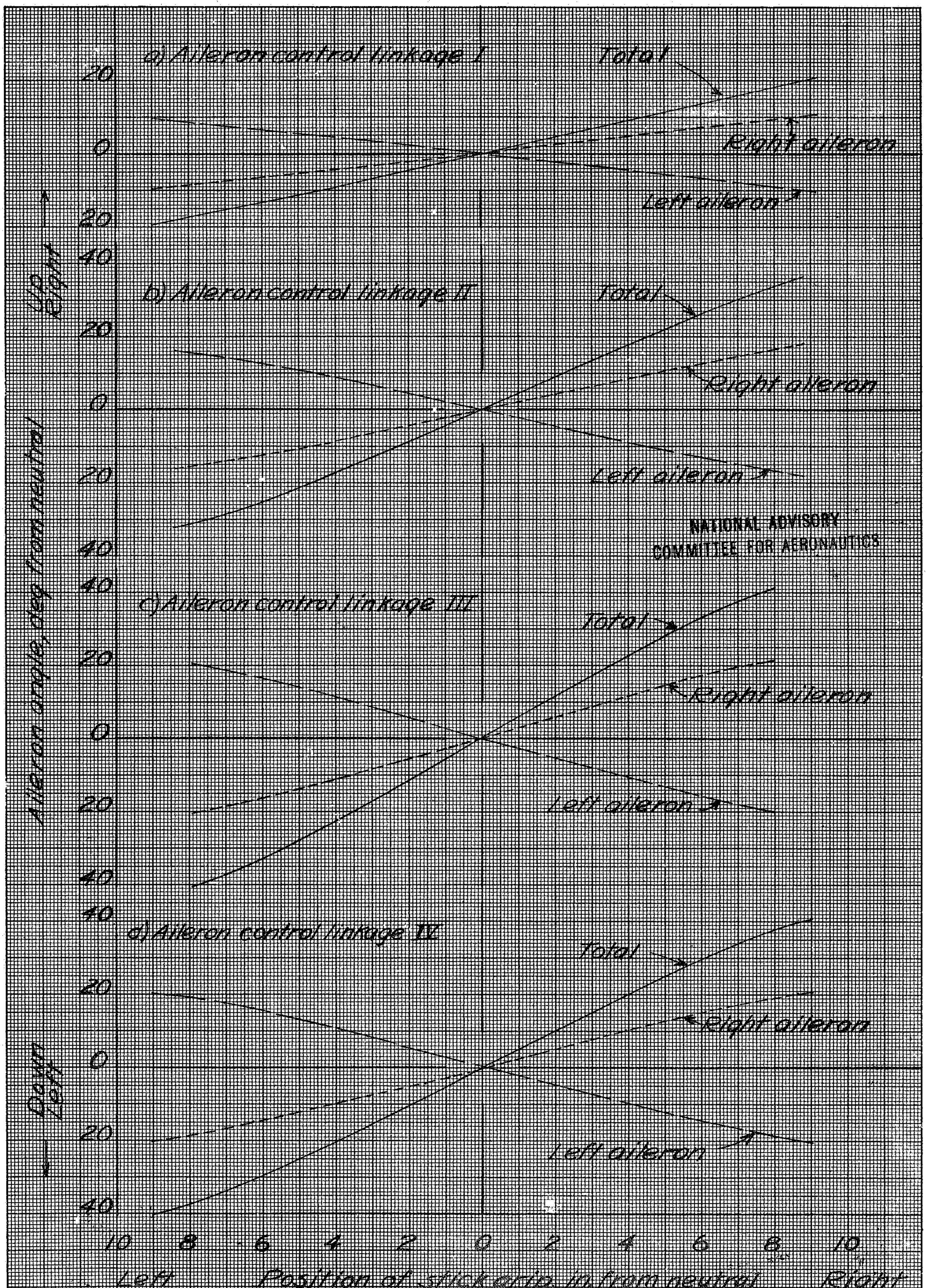


Figure 3.- Relations between position of ailerons and position of stick grip under no load. North American XP-51 airplane.

L-550

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

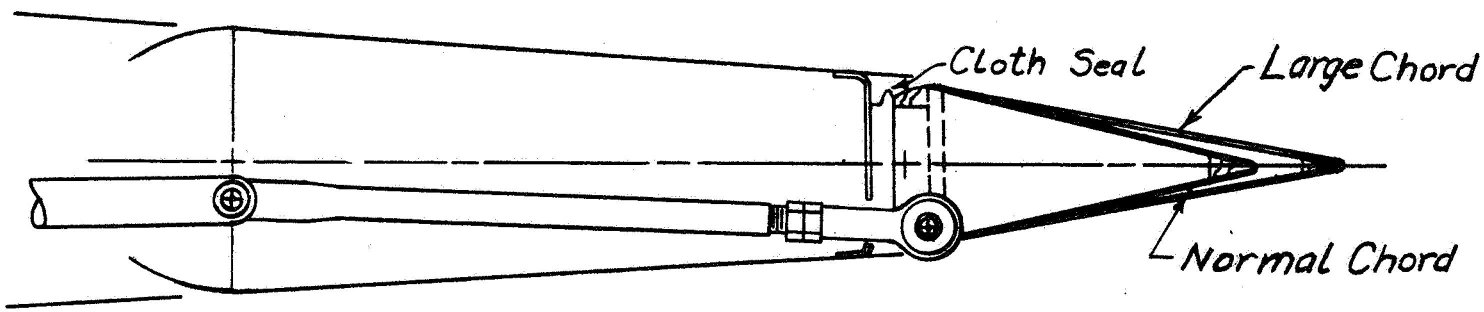


Figure 4. - Sections of sealed inset balancing tabs on 25° bevel-angle ailerons. North American XP-51 airplane

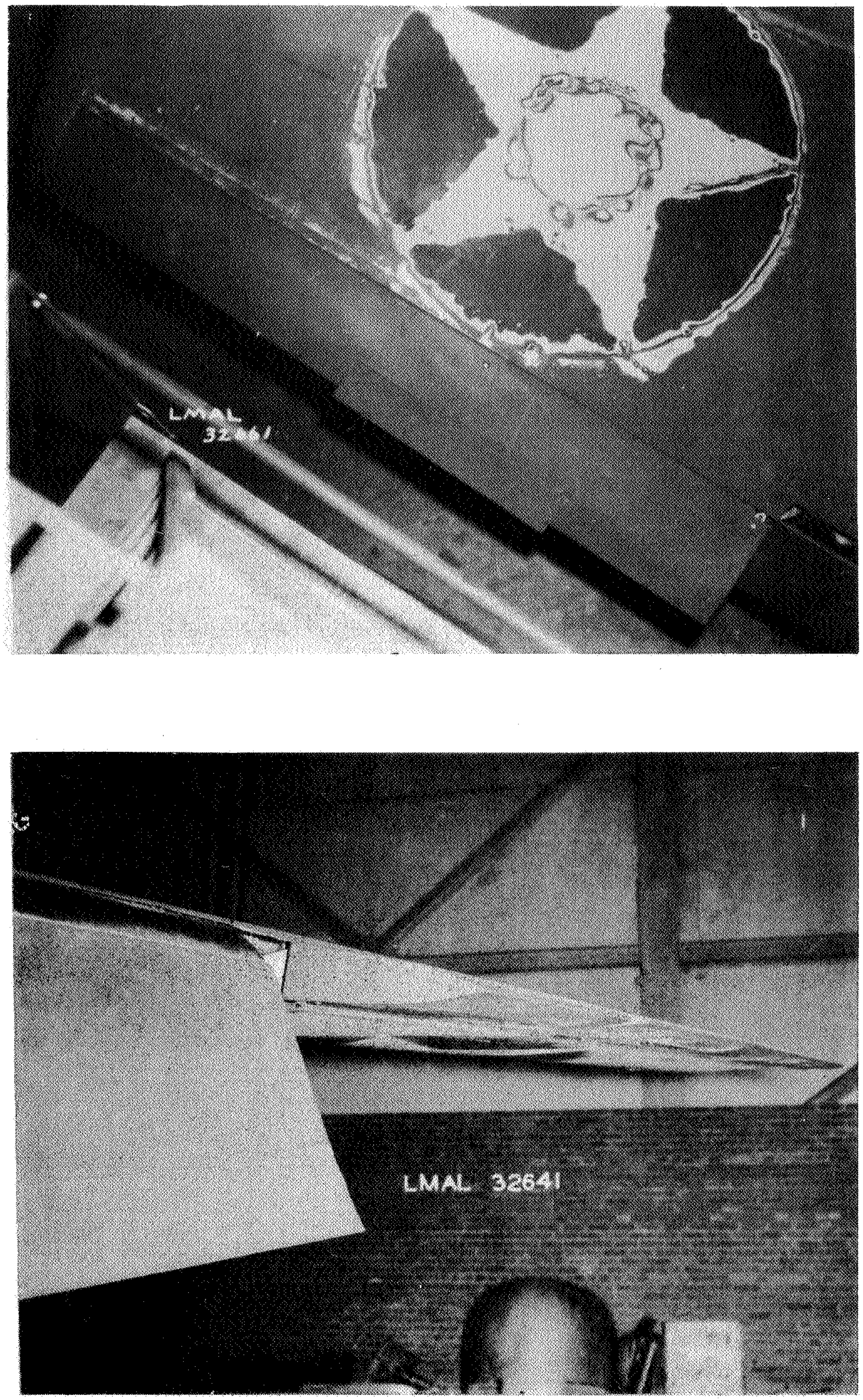


Figure 5.- Views of large-chord balancing tabs on 25° bevel-angle ailerons. North American XP-51 airplane.

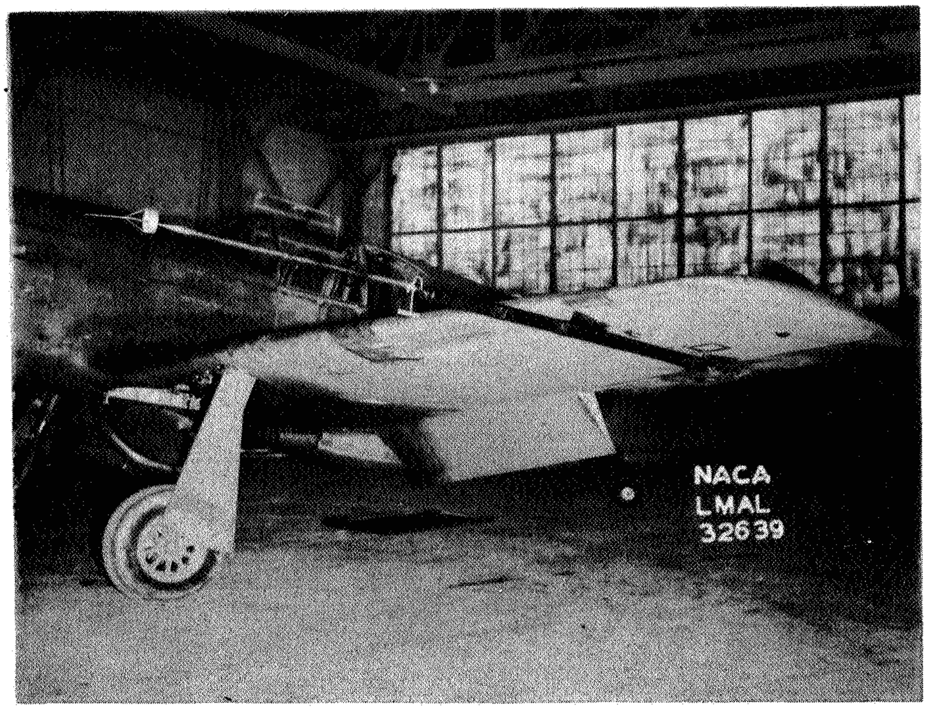


Figure 6.- View of NACA airspeed boom mounted on left wing of North American XP-51 airplane.

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

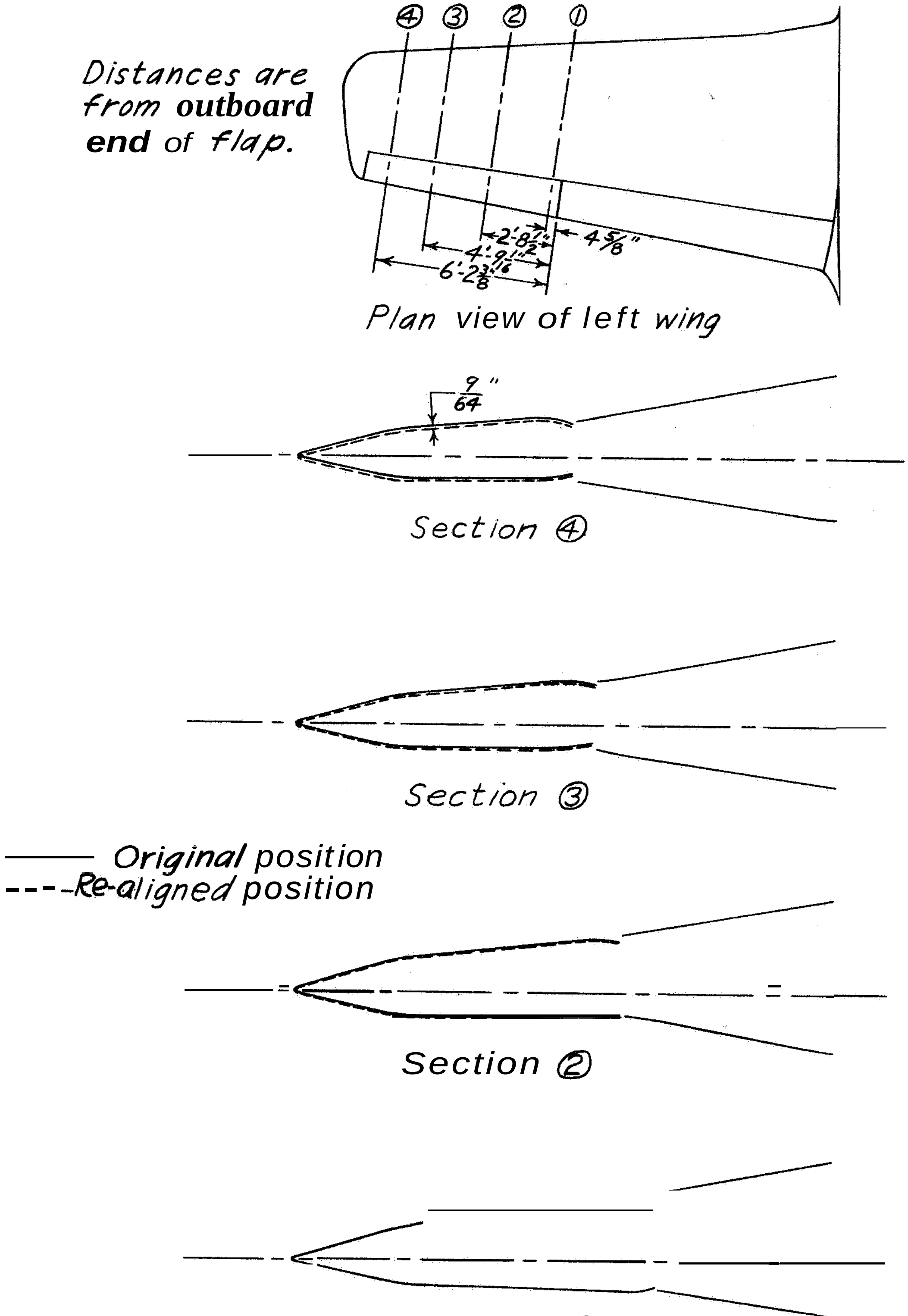


Figure 7.-Sections of left wing showing original and re-aligned positions of left aileron North American XP-51 airplane

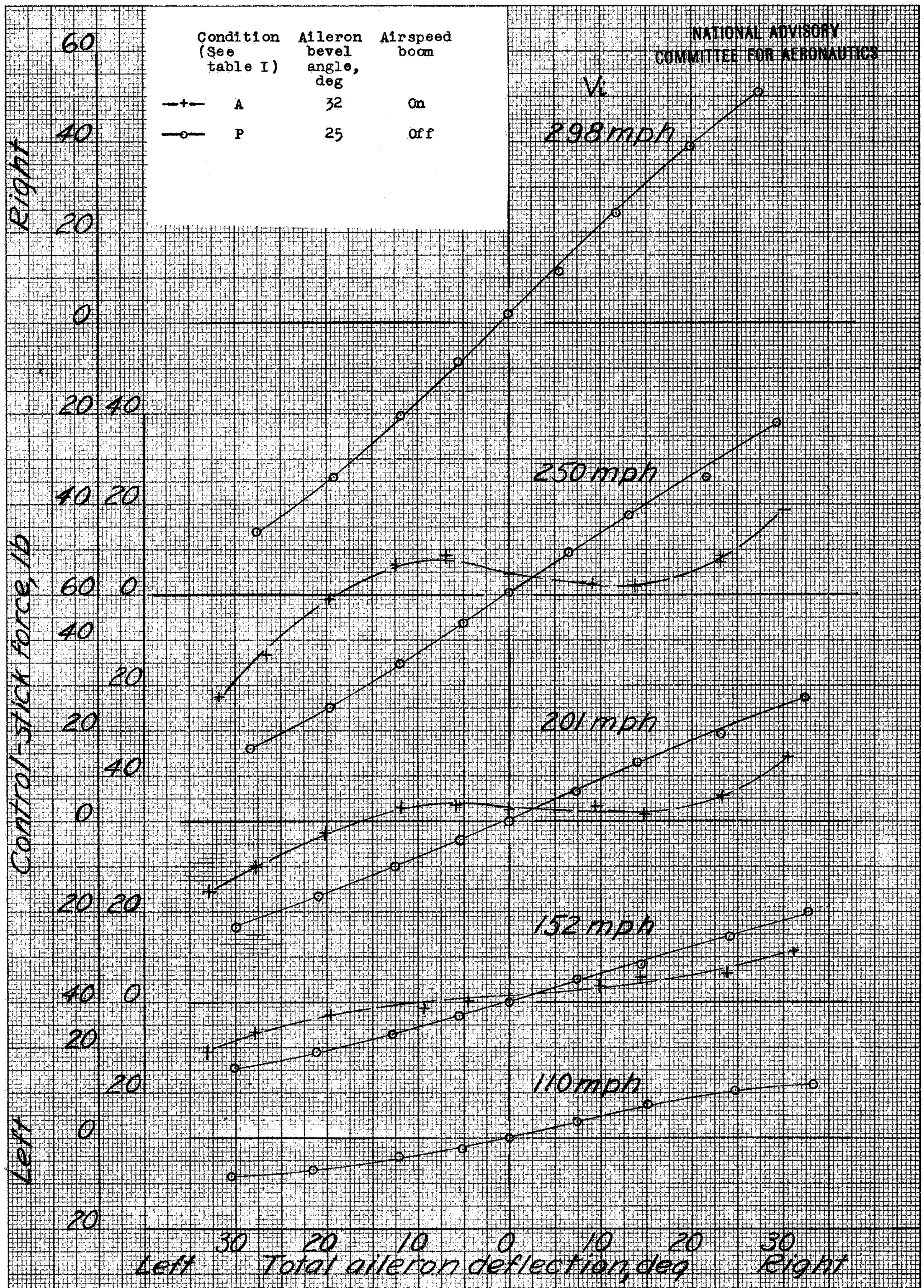


Figure 8.- Stick-force characteristics of 32°-bevel-angle ailerons. North American XP-51 airplane.

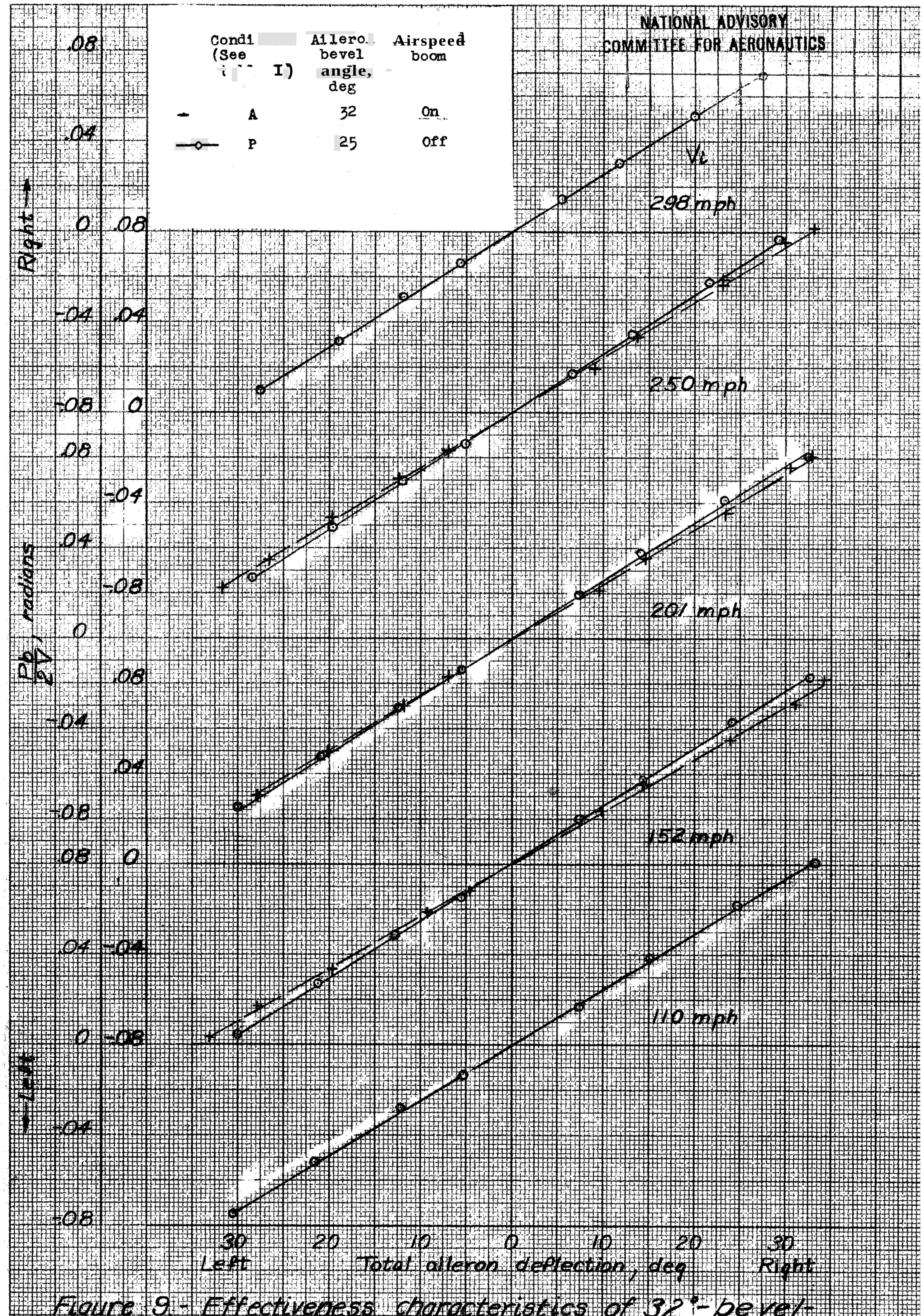


Figure 9.- Effectiveness characteristics of 32°-bevel-angle ailerons. North American XP-51 airplane.

L-550

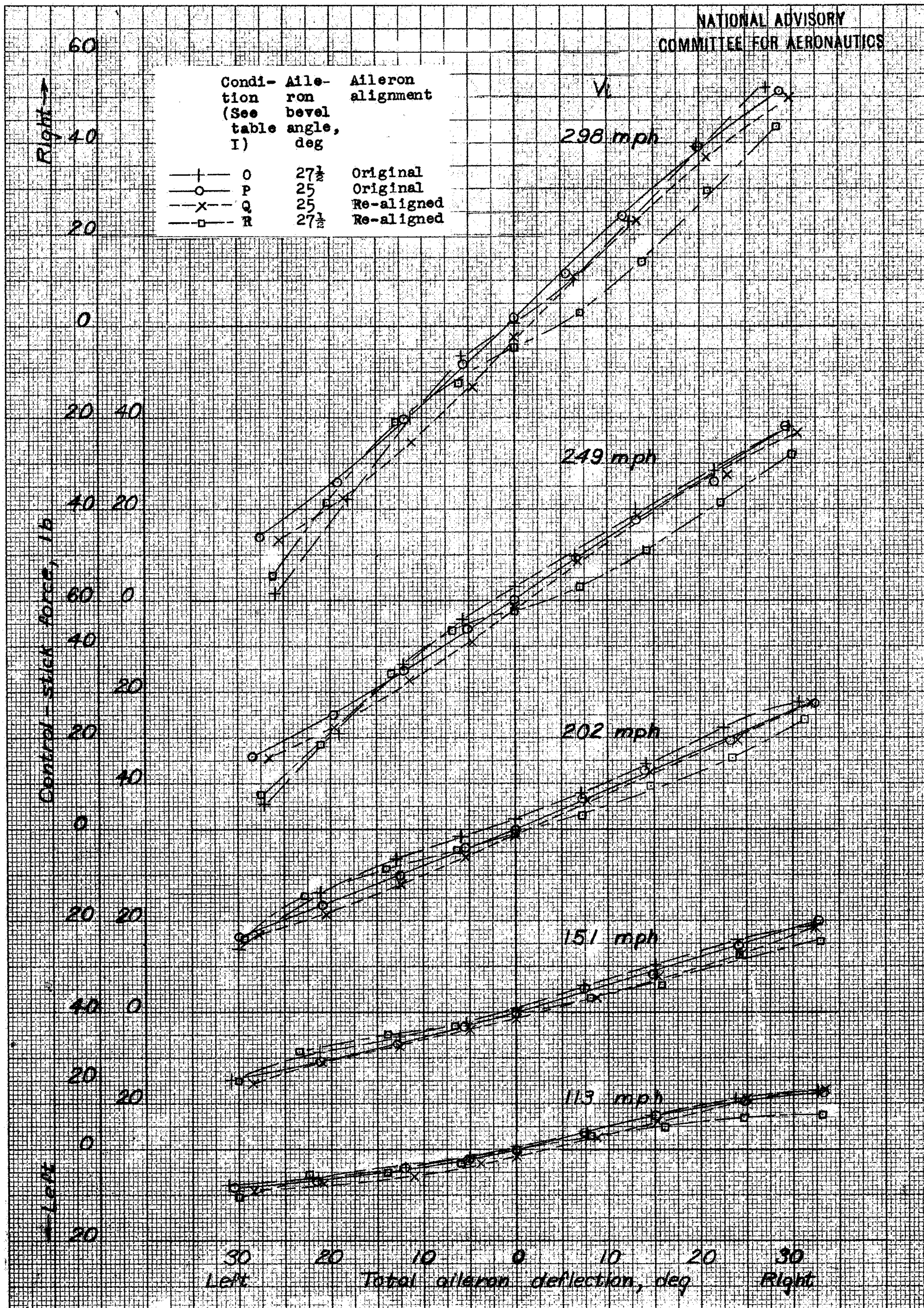


Figure 10- Effect of bevel angle and aileron alignment on stick-force characteristics of beveled trailing-edge ailerons North American XP-51 airplane

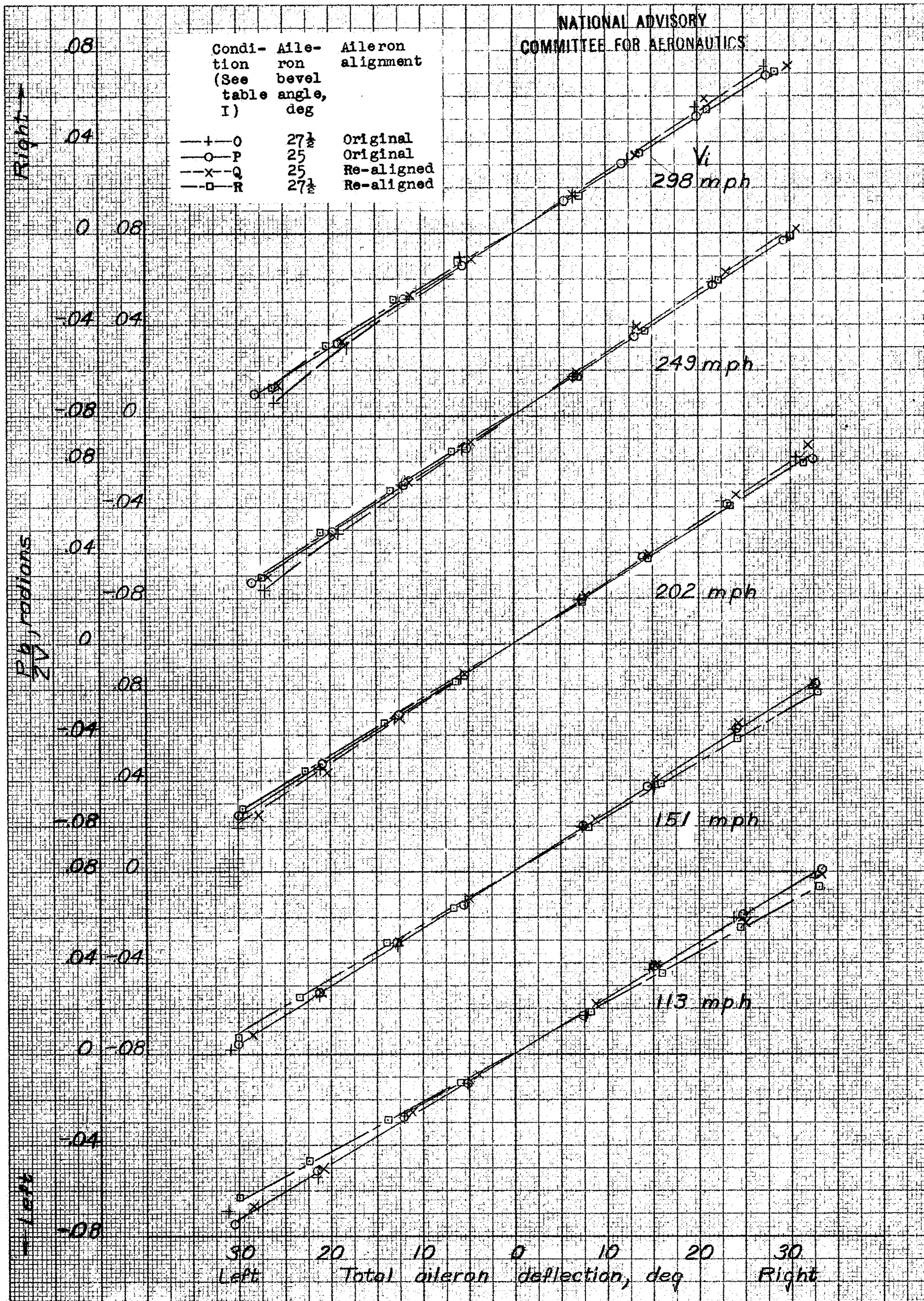


Figure 11.- Effect of bevel angle and aileron alignment on effectiveness characteristics of beveled trailing-edge ailerons North American XP-51 airplane

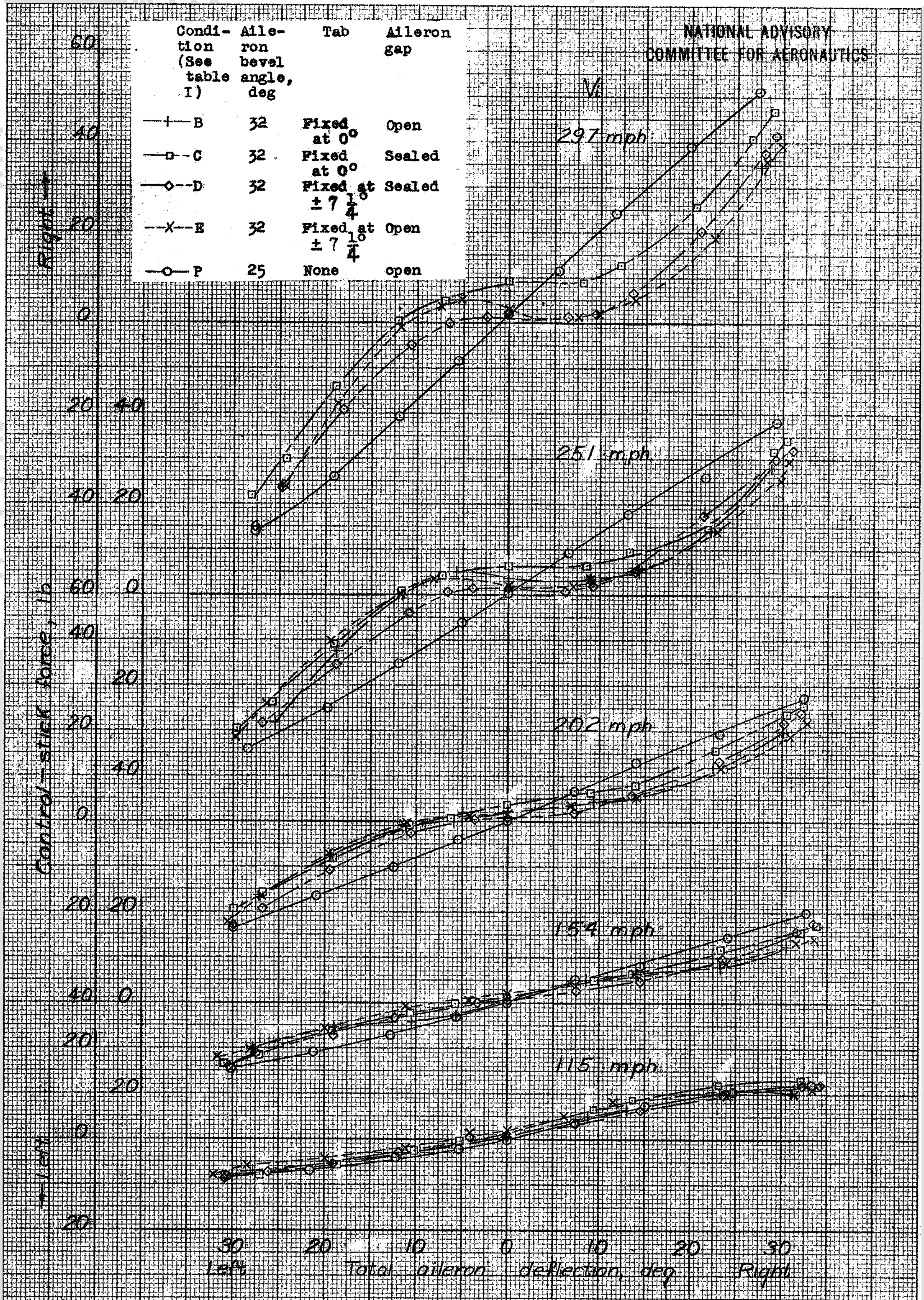


Figure 12- Stick-force characteristics of beveled trailing-edge ailerons with sealed aileron gaps North American XP-51 airplane

L-550

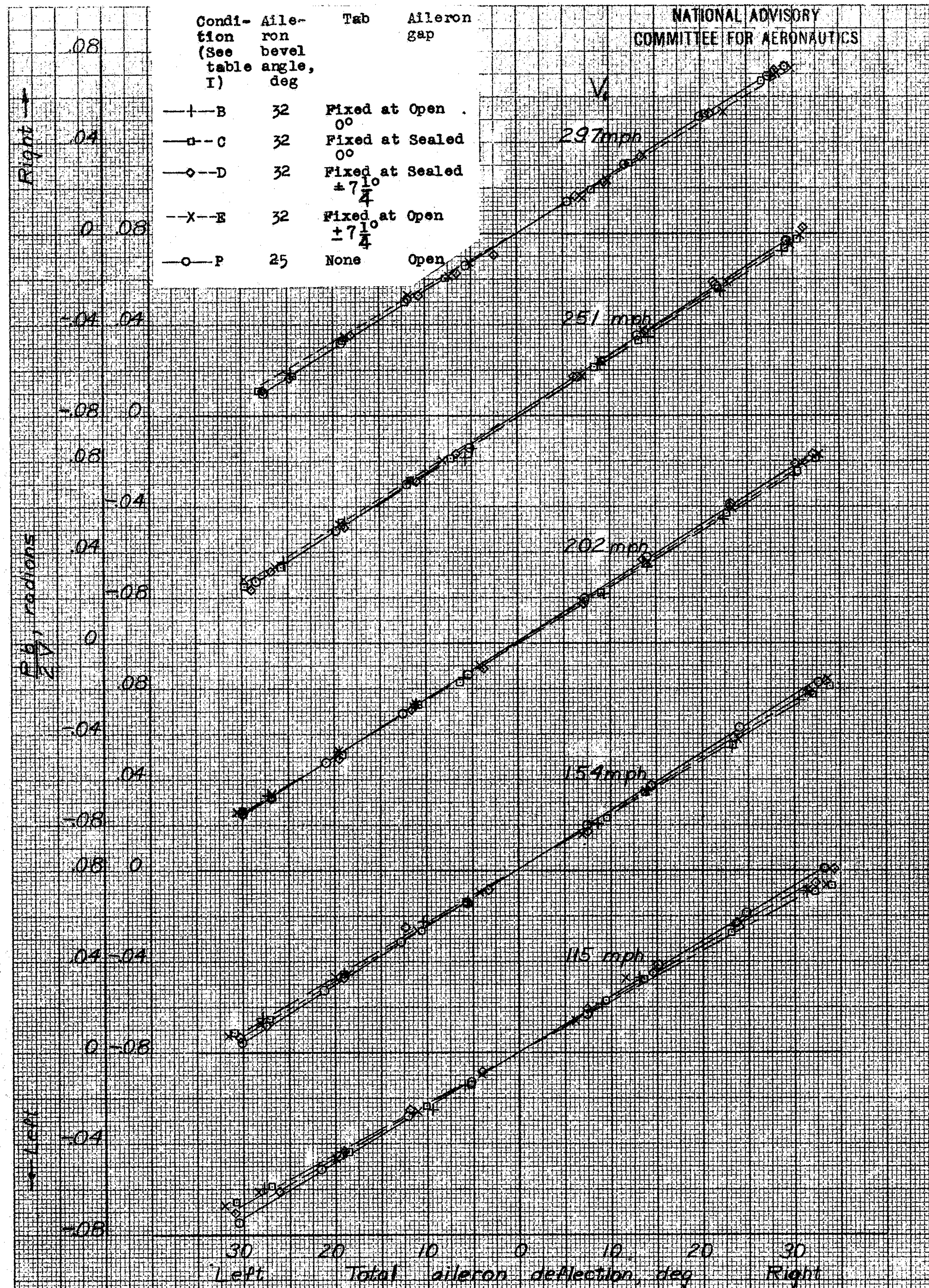


Figure 13.- Effectiveness characteristics of beveled trailing-edge ailerons with sealed aileron gaps. North American XP-51 airplane

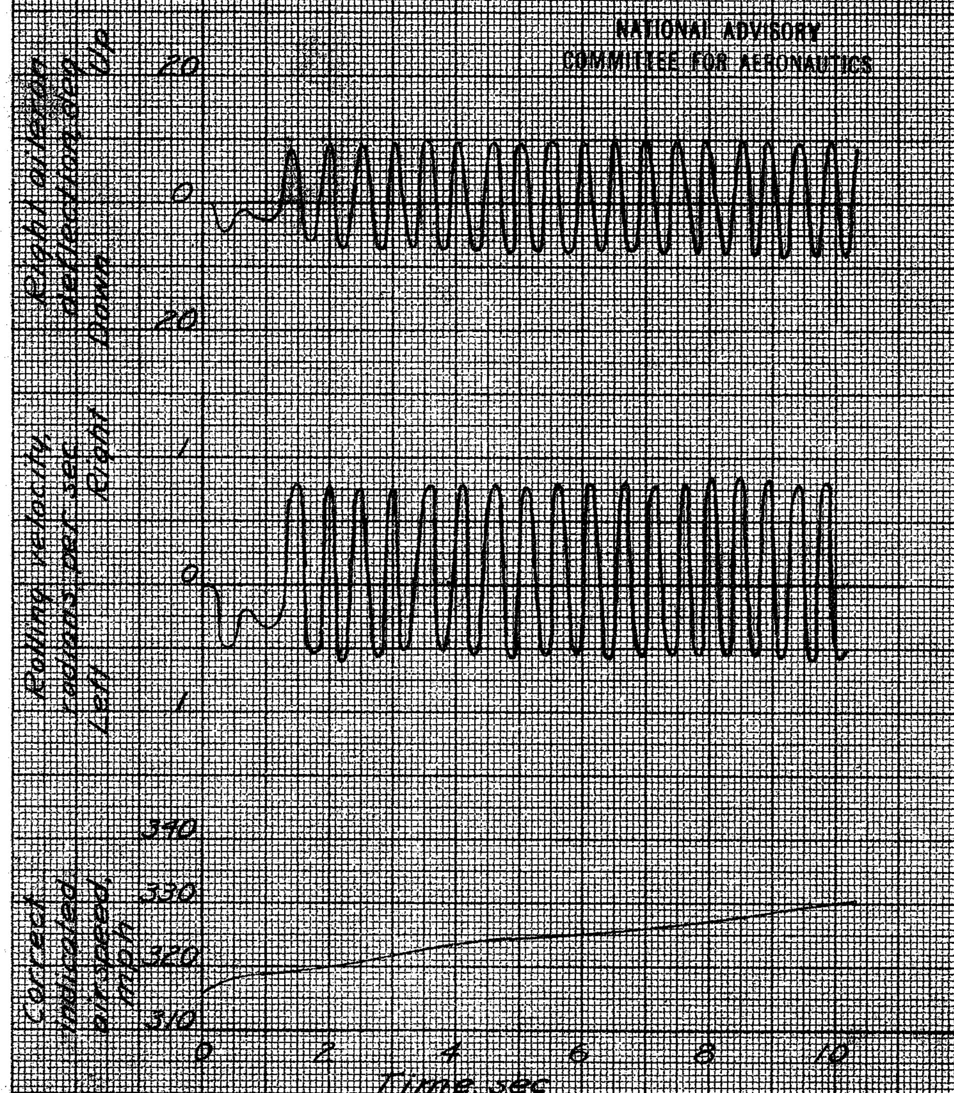


Figure 14.- Time history of stick-free oscillation of 32° bevel-angle ailerons with sealed nose gaps. Condition D. North American XP-51 airplane.

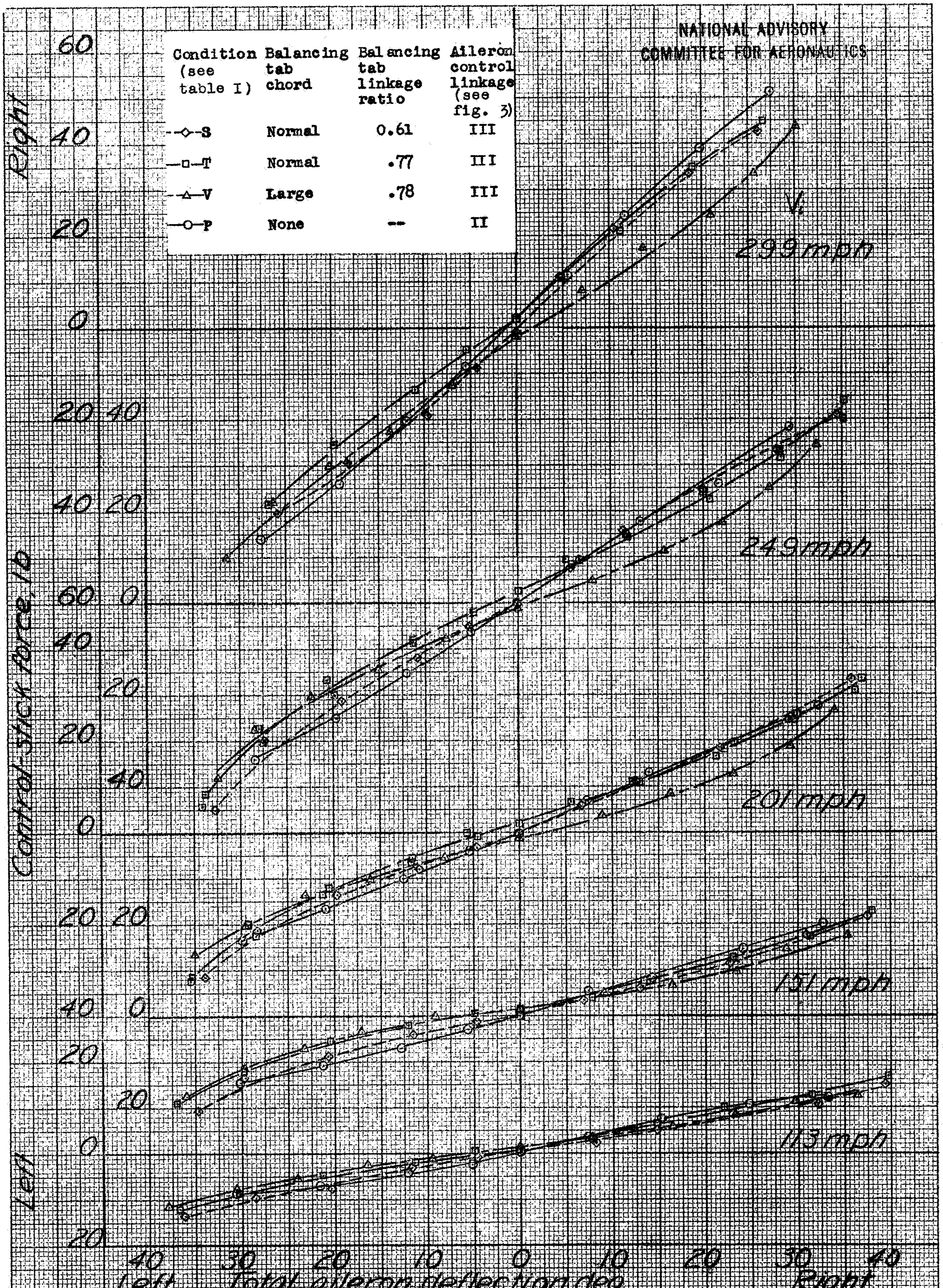


Figure 15.- Effect of balancing tab linkage ratio and chord on stick-force characteristics North American XP-51 airplane.

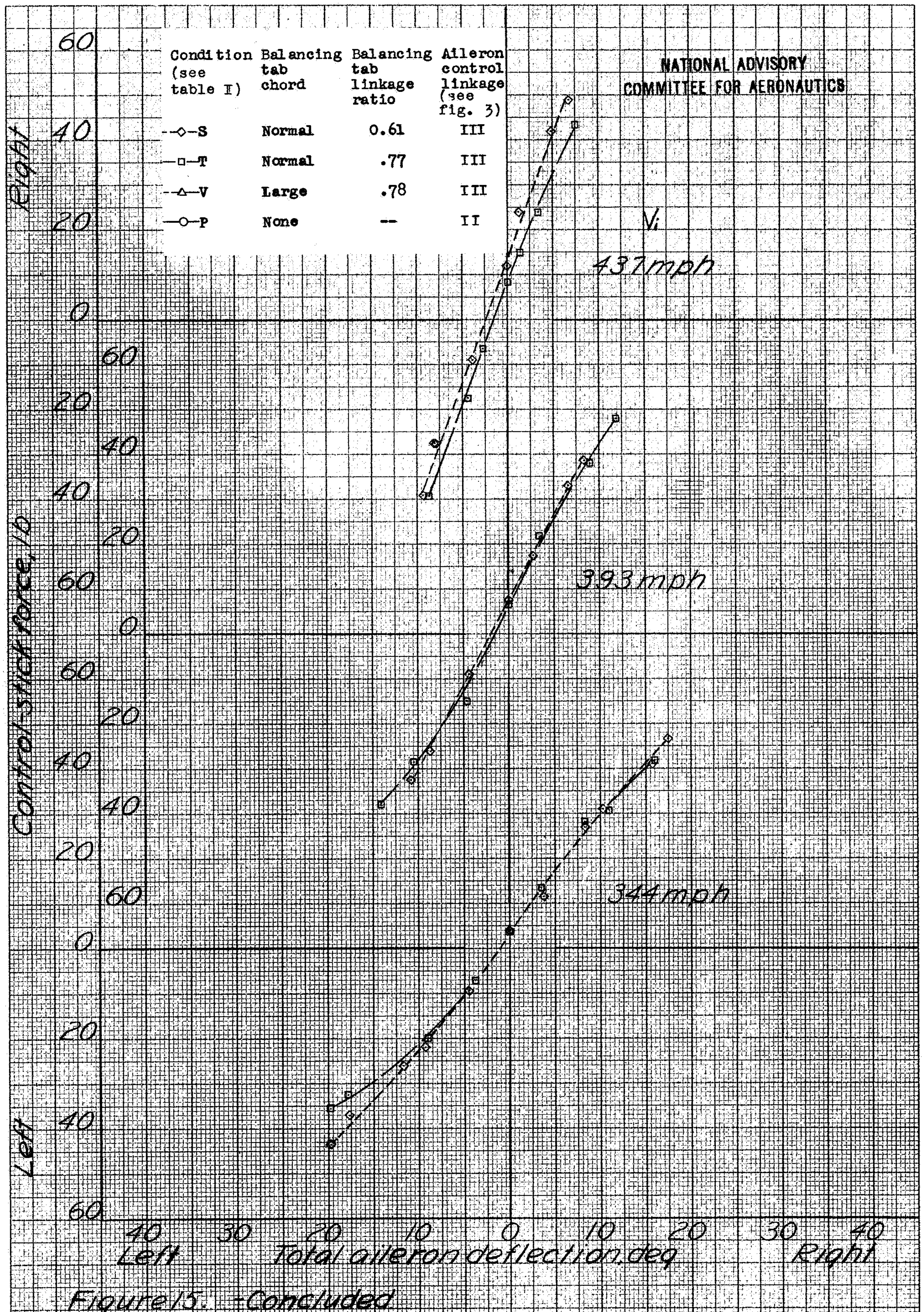


Figure 15. - Concluded

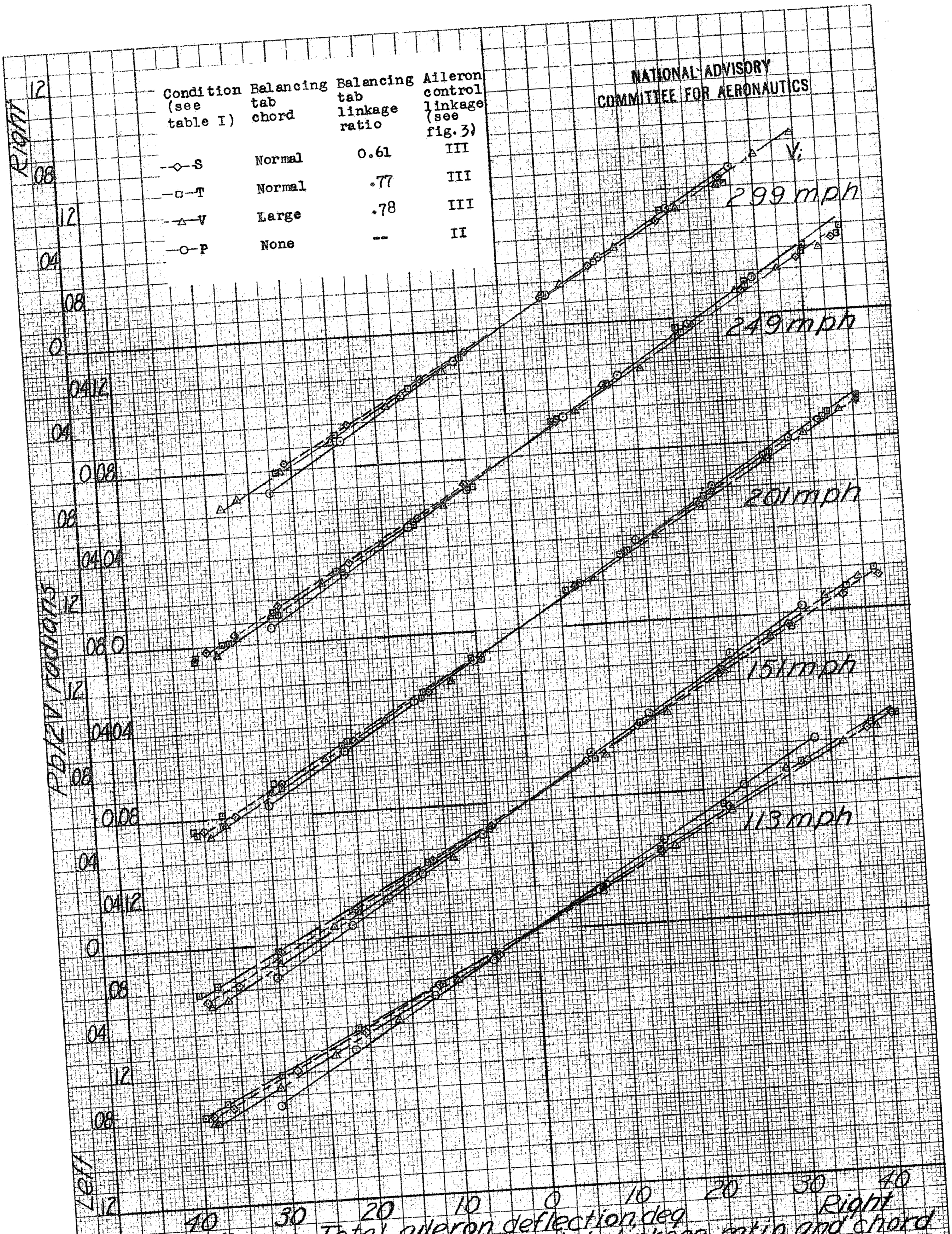


Figure 16.- Effect of balancing tab linkage ratio and chord on aileron effectiveness. North American XP-51 airplane.

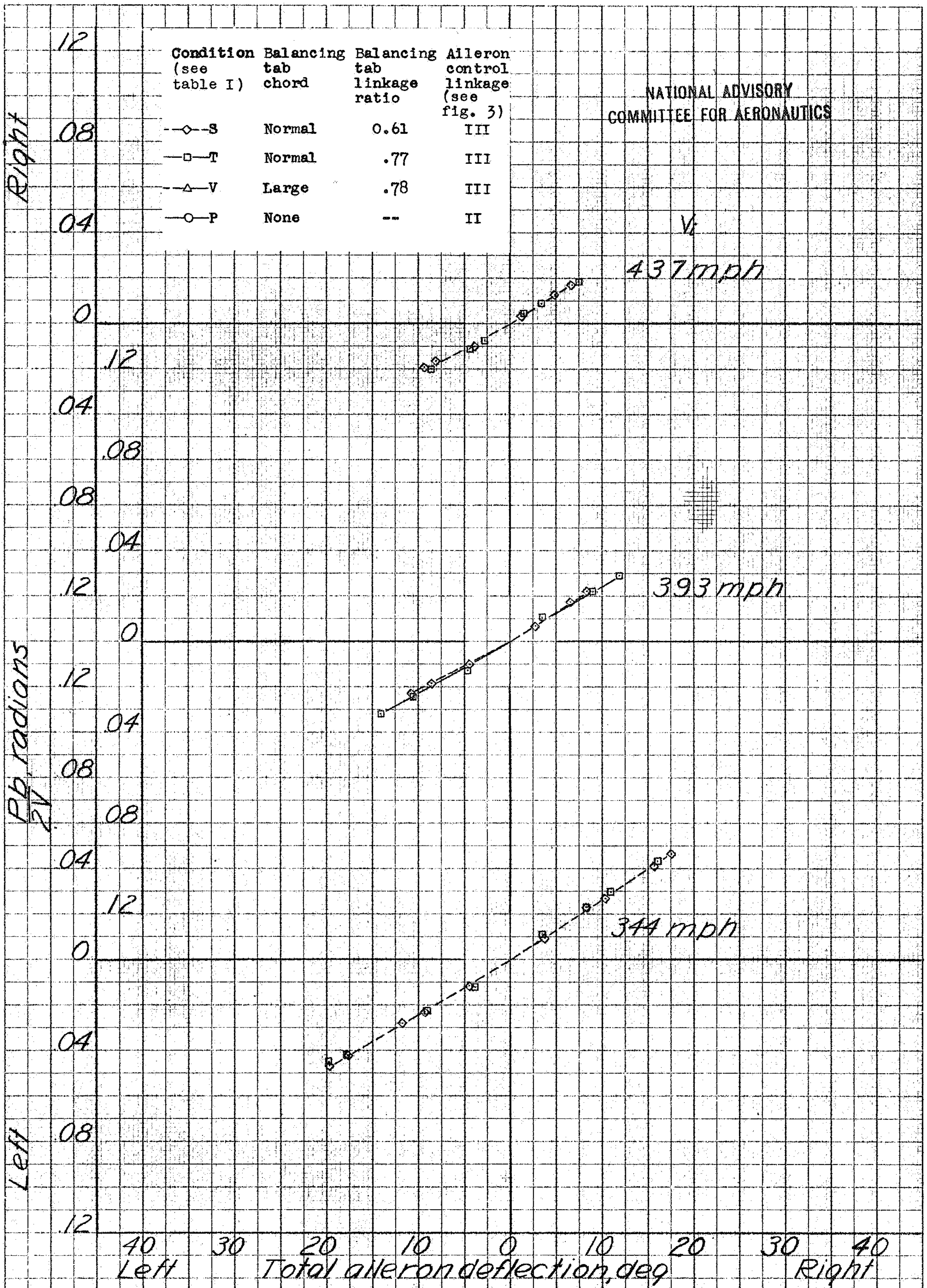


Figure 16 - Concluded.

L-530

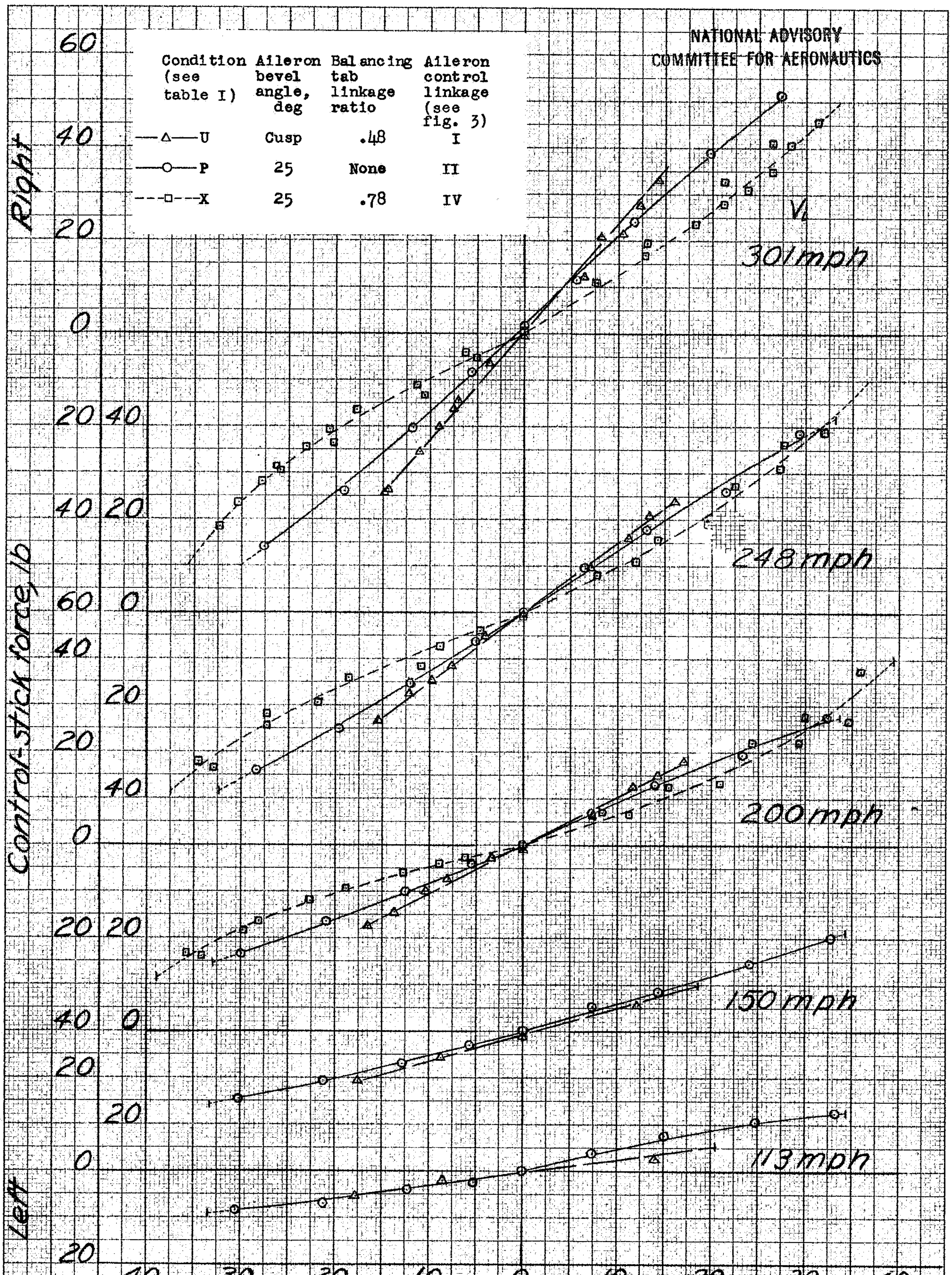


Figure 17.- Comparison of stick force characteristics of 25°-bevel-angle ailerons with balancing tabs, cusp ailerons with balancing tabs, and 25°-bevel-angle ailerons. North American XP-51 airplane.

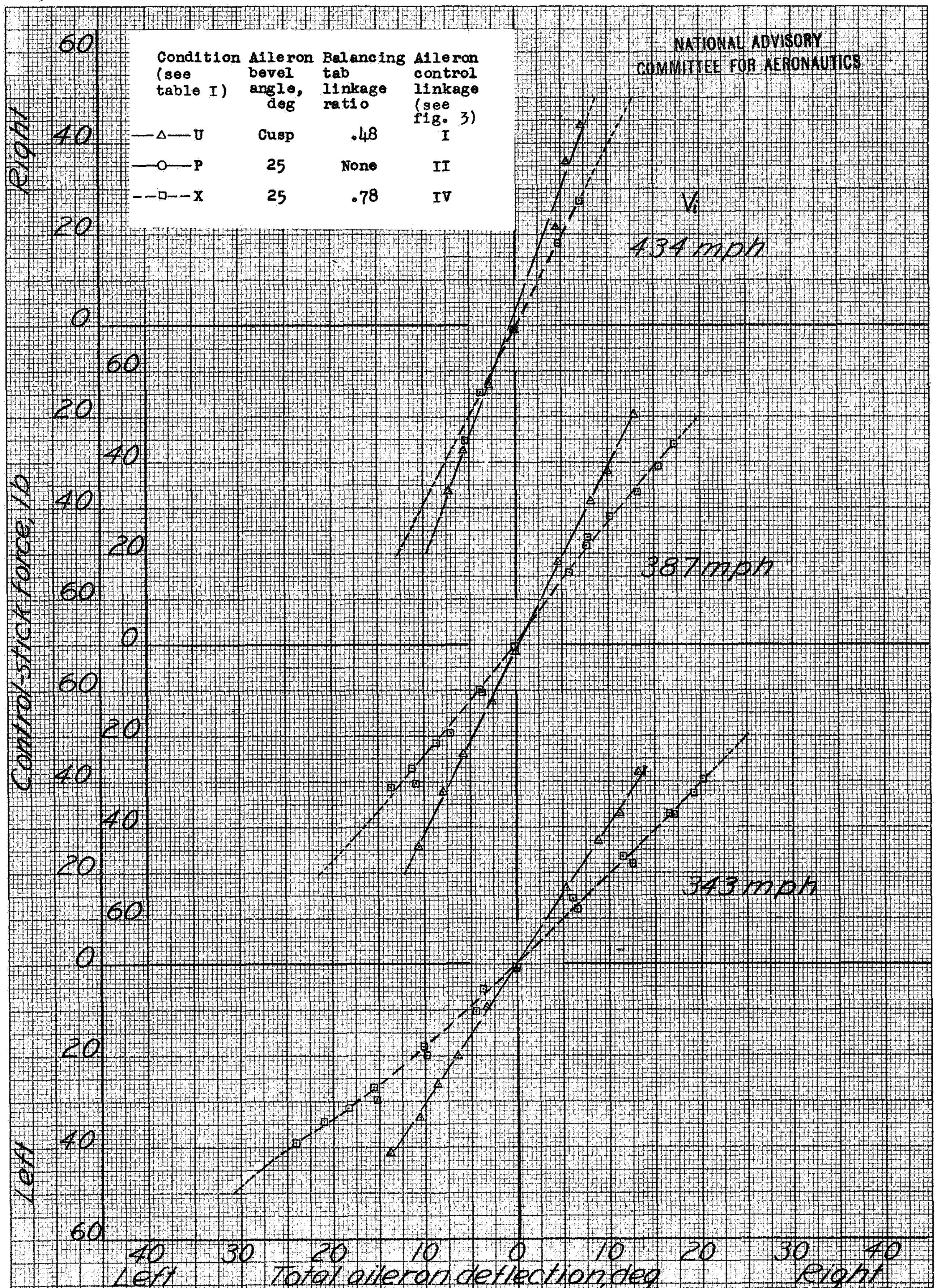


Figure 17.- Concluded.

L-550

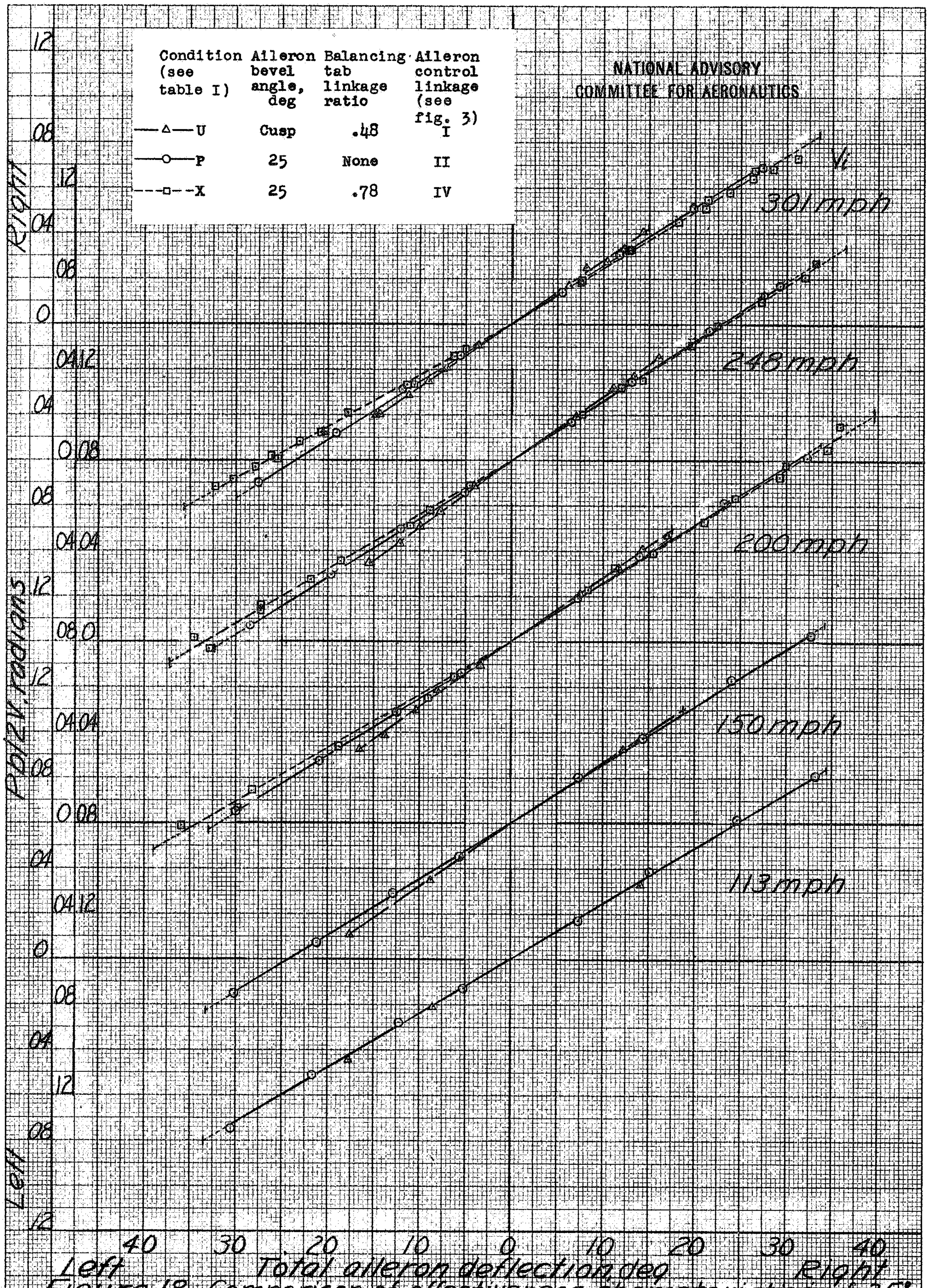


Figure 18.- Comparison of effectiveness characteristics of 25°-bevel-angle ailerons with balancing tabs, cusp ailerons with balancing tabs, and 25° bevel-angle ailerons. North American XP-51 airplane.

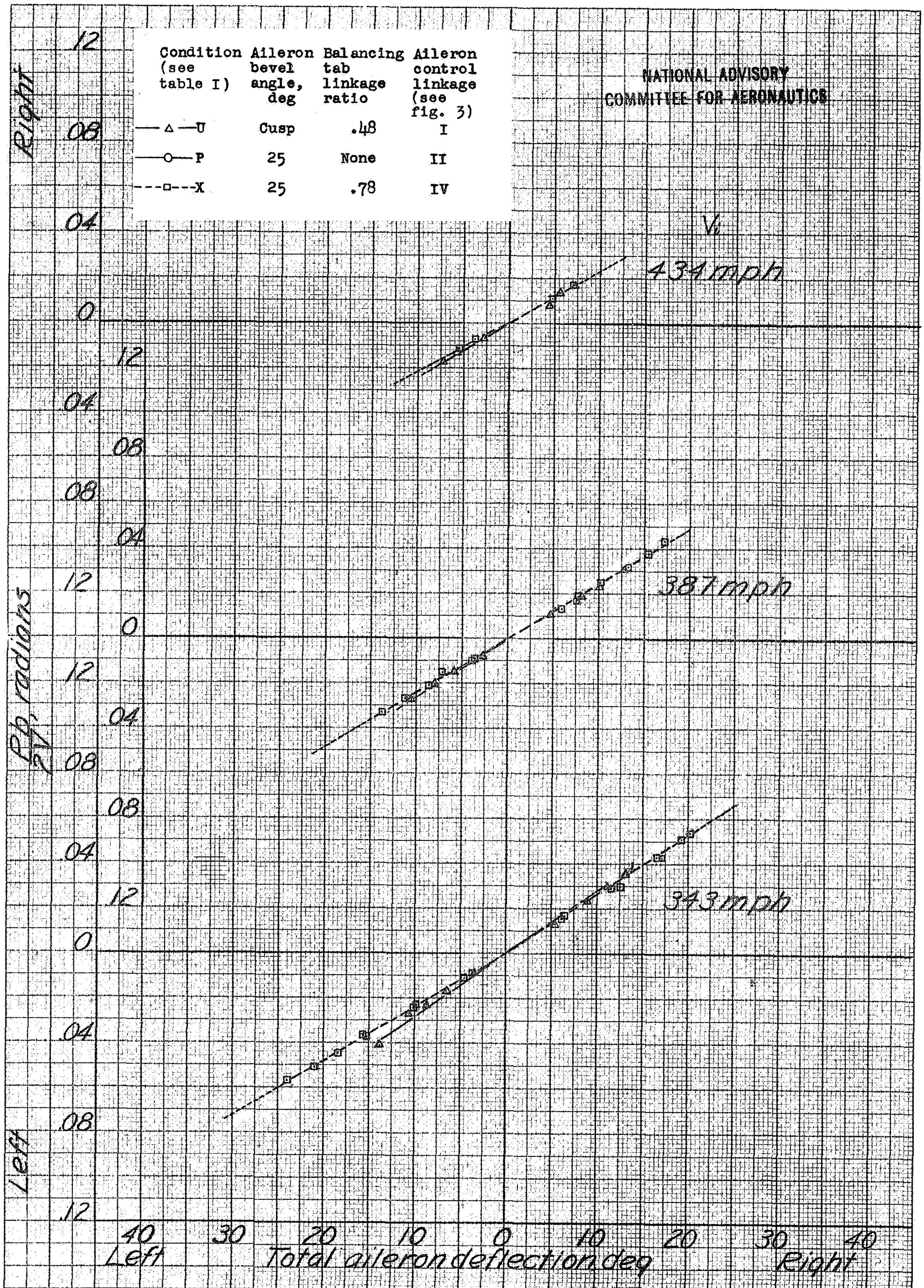


Figure 18. -Concluded

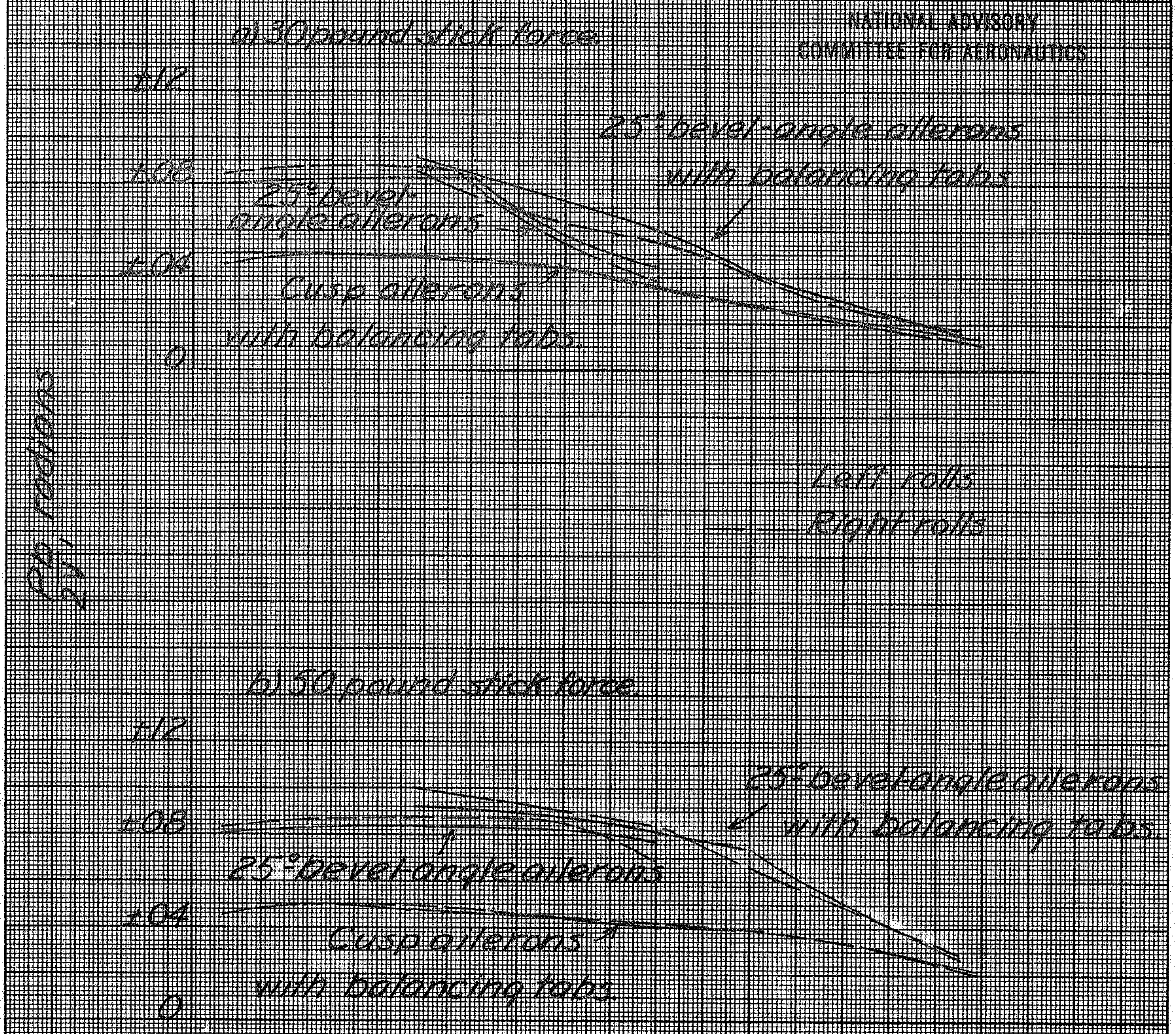


Figure 19.—Comparison of aileron characteristics of 25° bevel-angle ailerons, cusp ailerons with balancing tabs, and 25° bevel-angle ailerons with balancing tabs. Data from figures 17 and 18. North American XP-51 airplane.

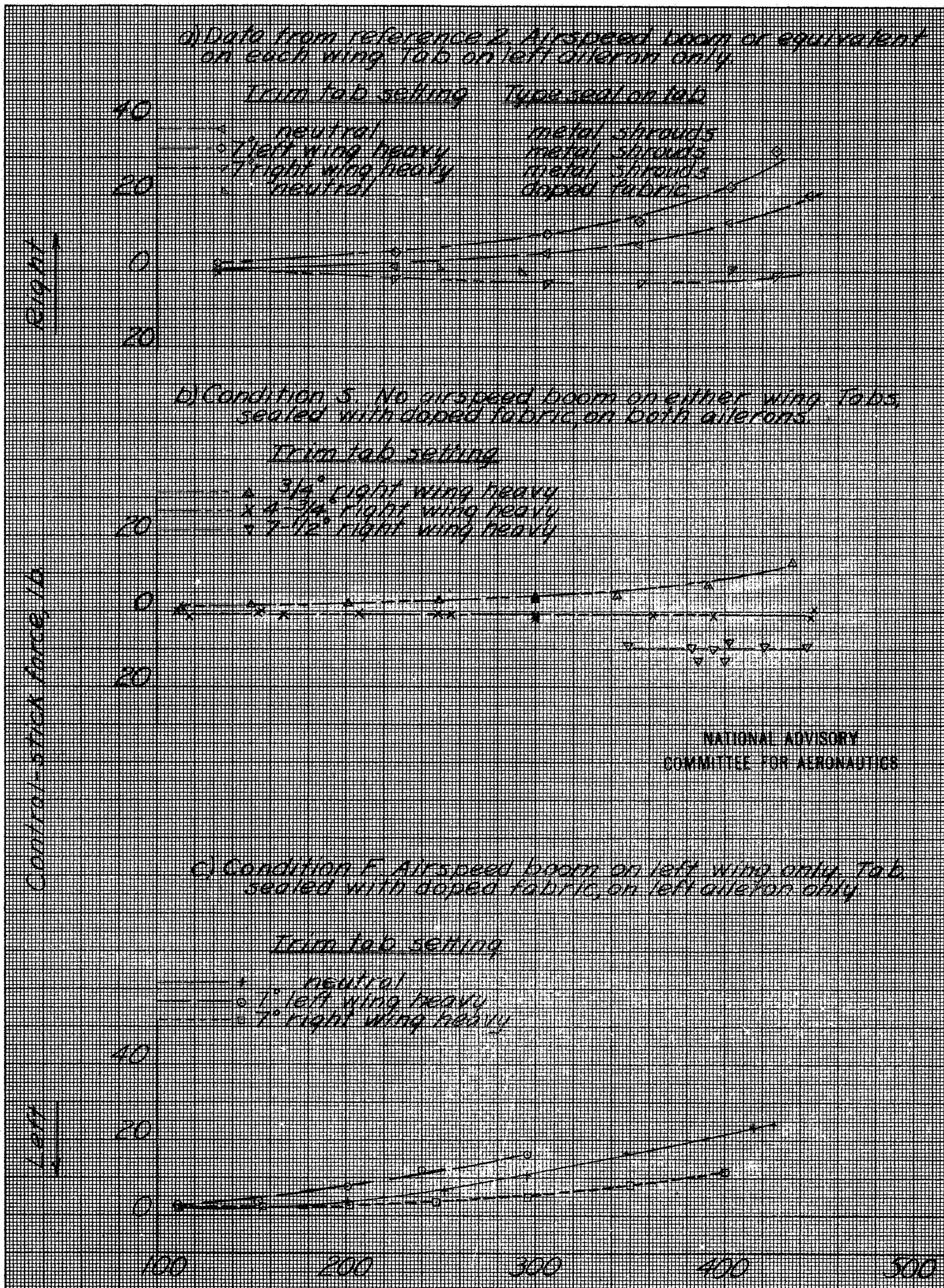


Figure 20.- Aileron trim characteristics of beveled trailing-edge ailerons with 25° bevel angle and inset normal-chord tabs. North American XP-51 airplane.

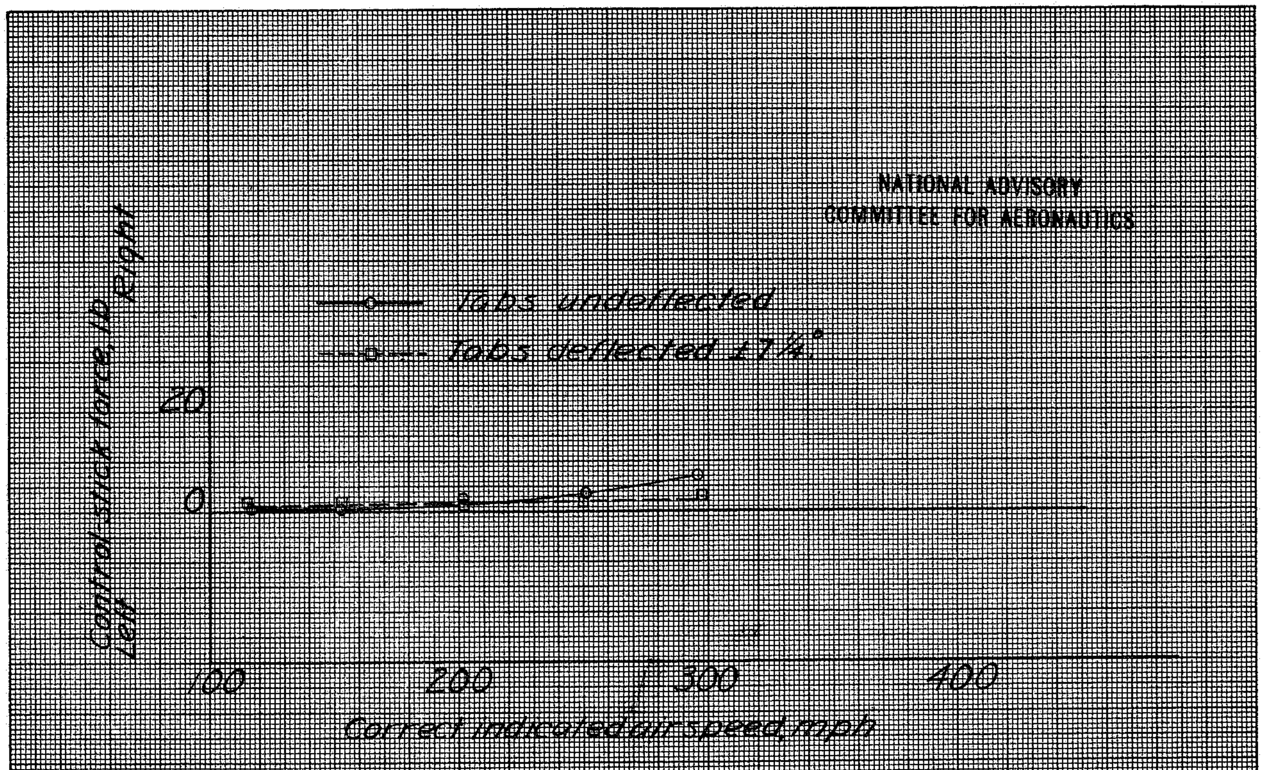


Figure 21. - Aileron trim characteristics of beveled trailing-edge ailerons with 32° bevel angle and fixed external tabs. North American XP-51 airplane.

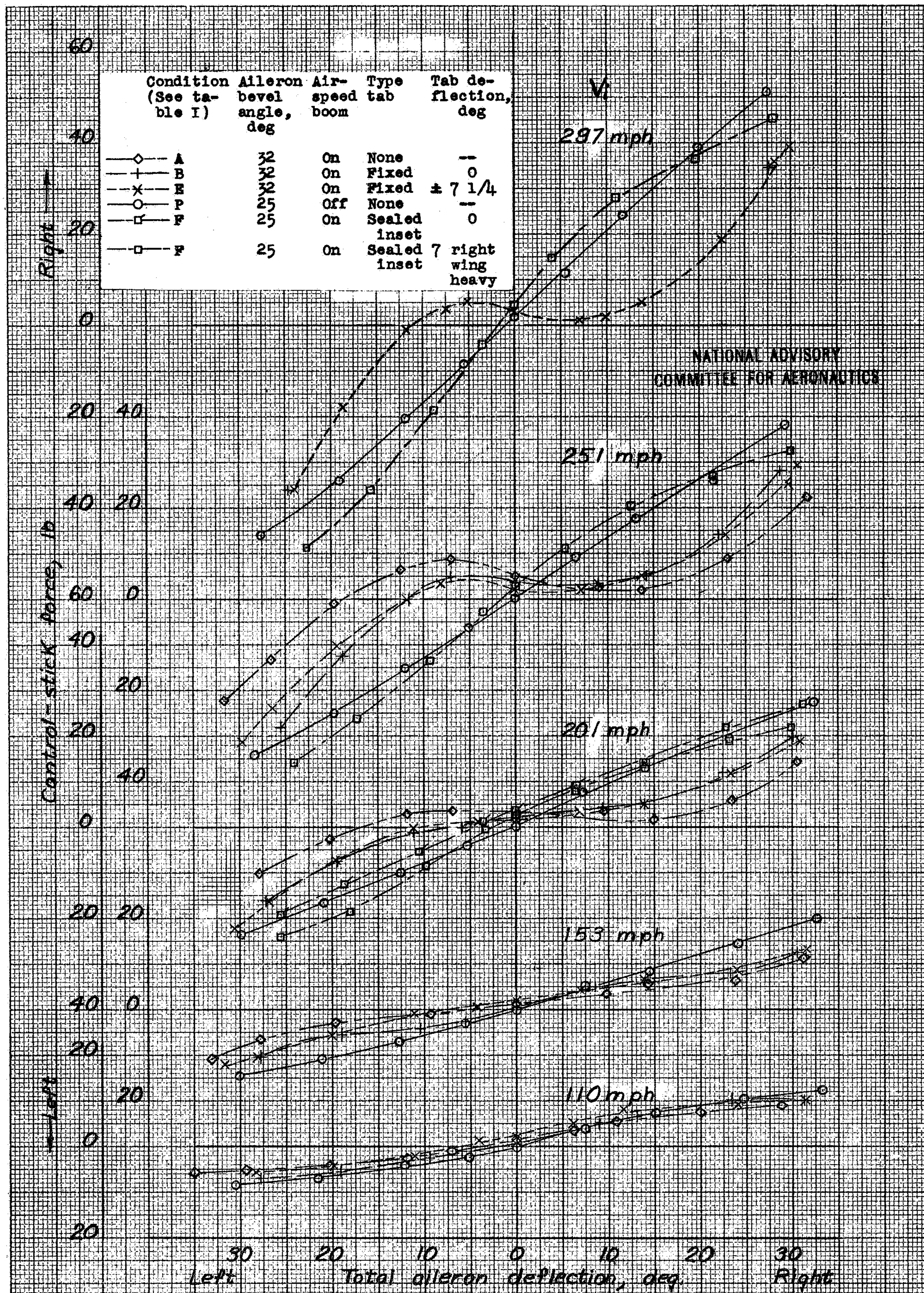


Figure 22.- Stick-force characteristics of beveled trailing-edge ailerons with fixed and inset tabs. North American XP-51 airplane

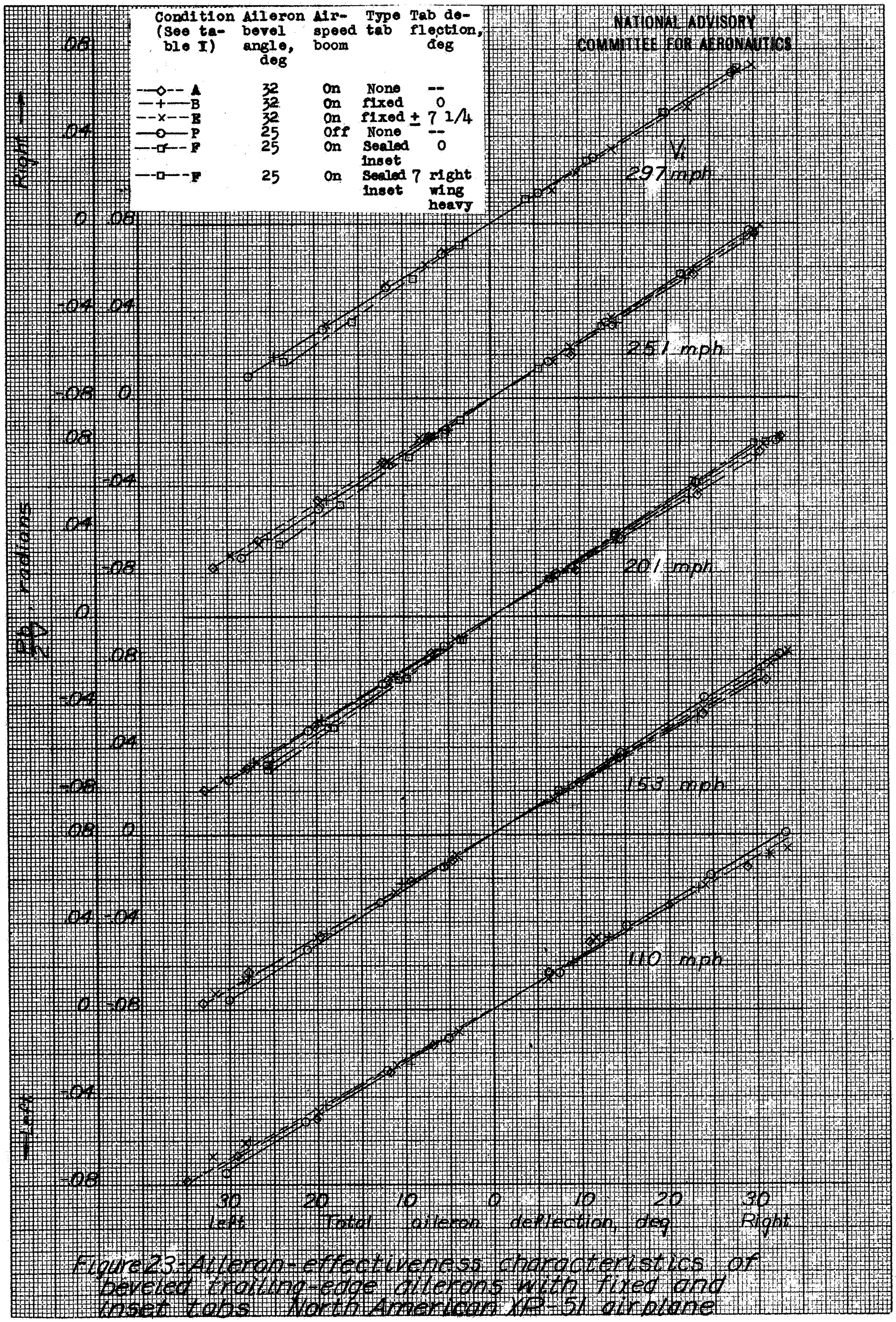


Figure 23.- Aileron-effectiveness characteristics of beveled trailing-edge ailerons with fixed and inset tabs. North American XP-51 airplane.

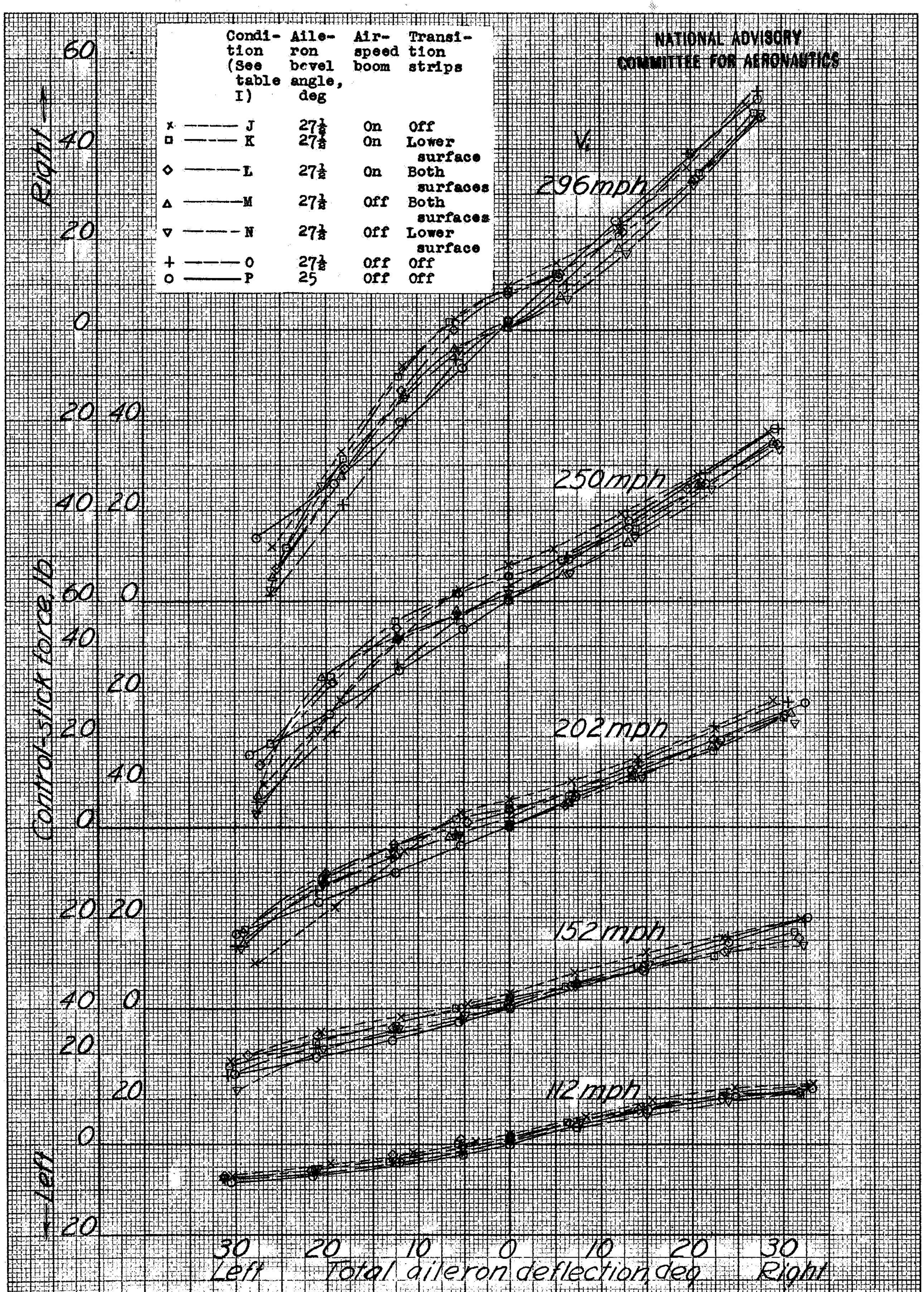


Figure 24.-Effect of airspeed boom and transition strips on stick-force characteristics of 27½° bevel angle ailerons. North American XP-51 airplane.

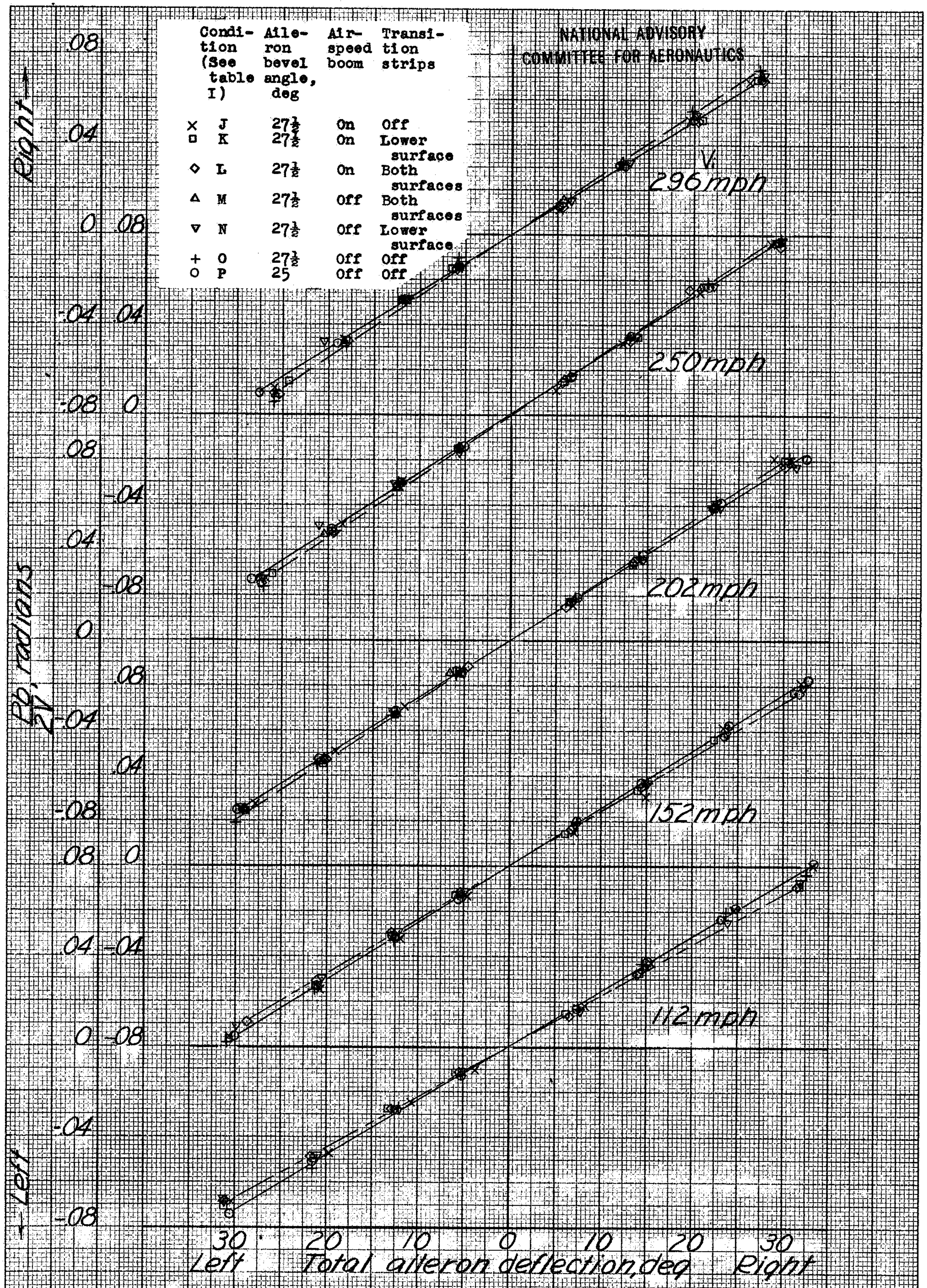


Figure 25.- Effect of airspeed boom and transition strips on the aileron-effectiveness characteristics of 27½° bevel angle ailerons North American XP-51 airplane

L-550

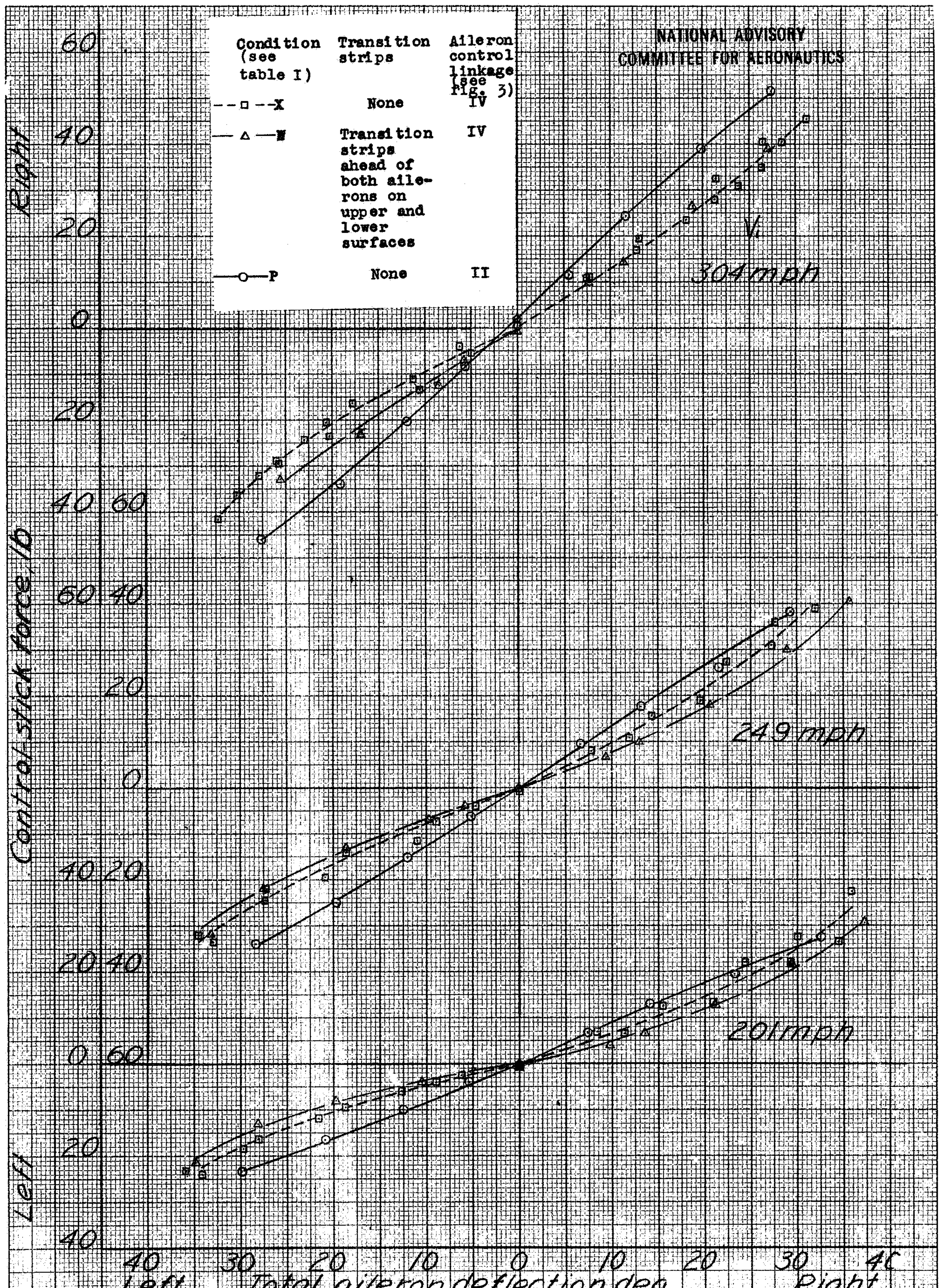


Figure 26.- Effect of transition strips on stick-force characteristics of beveled trailing-edge ailerons. 25° bevel-angle ailerons with balancing tabs. North American XP-51 airplane.

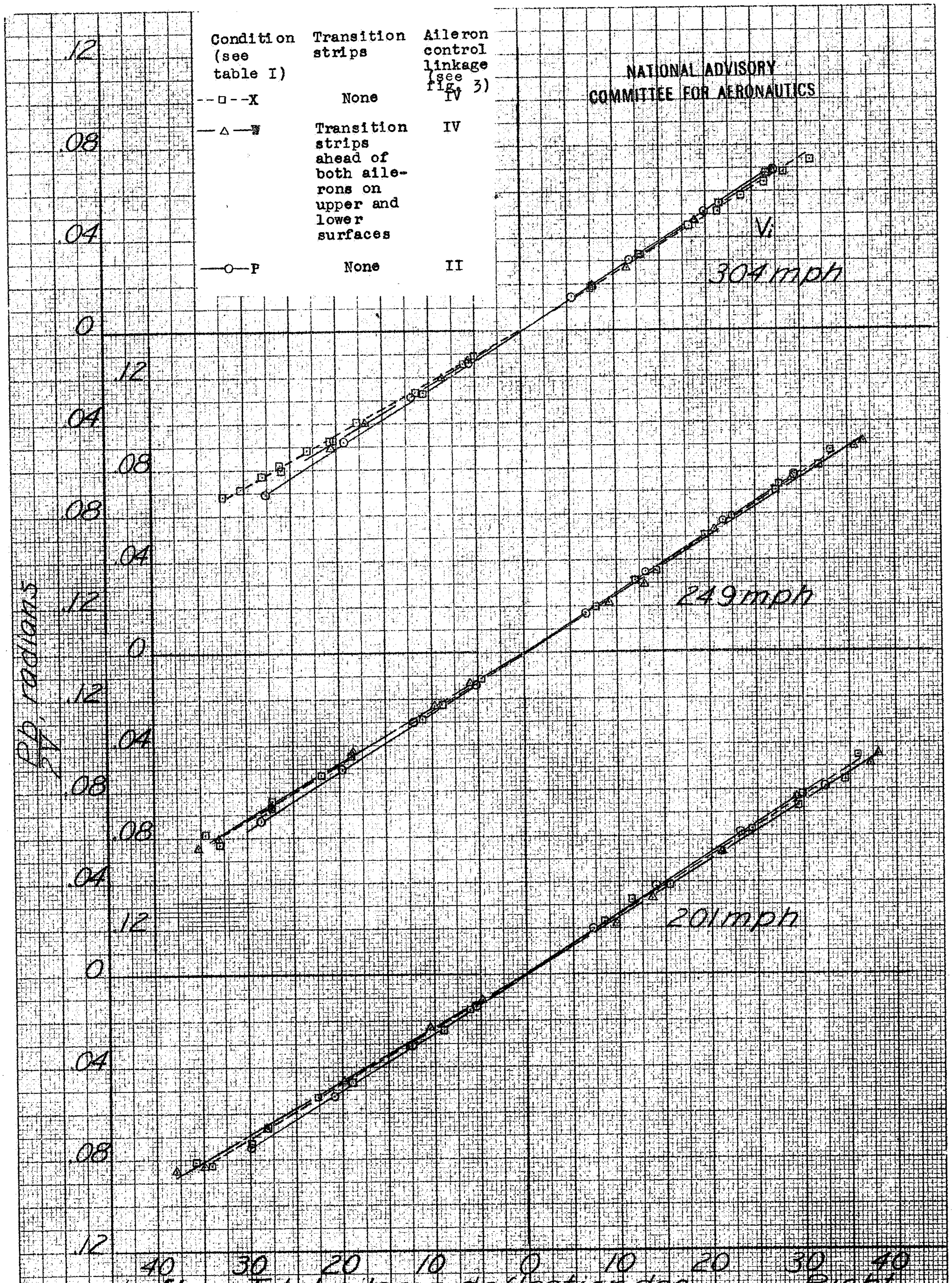


Figure 27.- Effect of transition strips on aileron-effectiveness characteristics of beveled trailing-edge ailerons. 25° bevel-angle ailerons with balancing tabs North American XP-51 airplane.

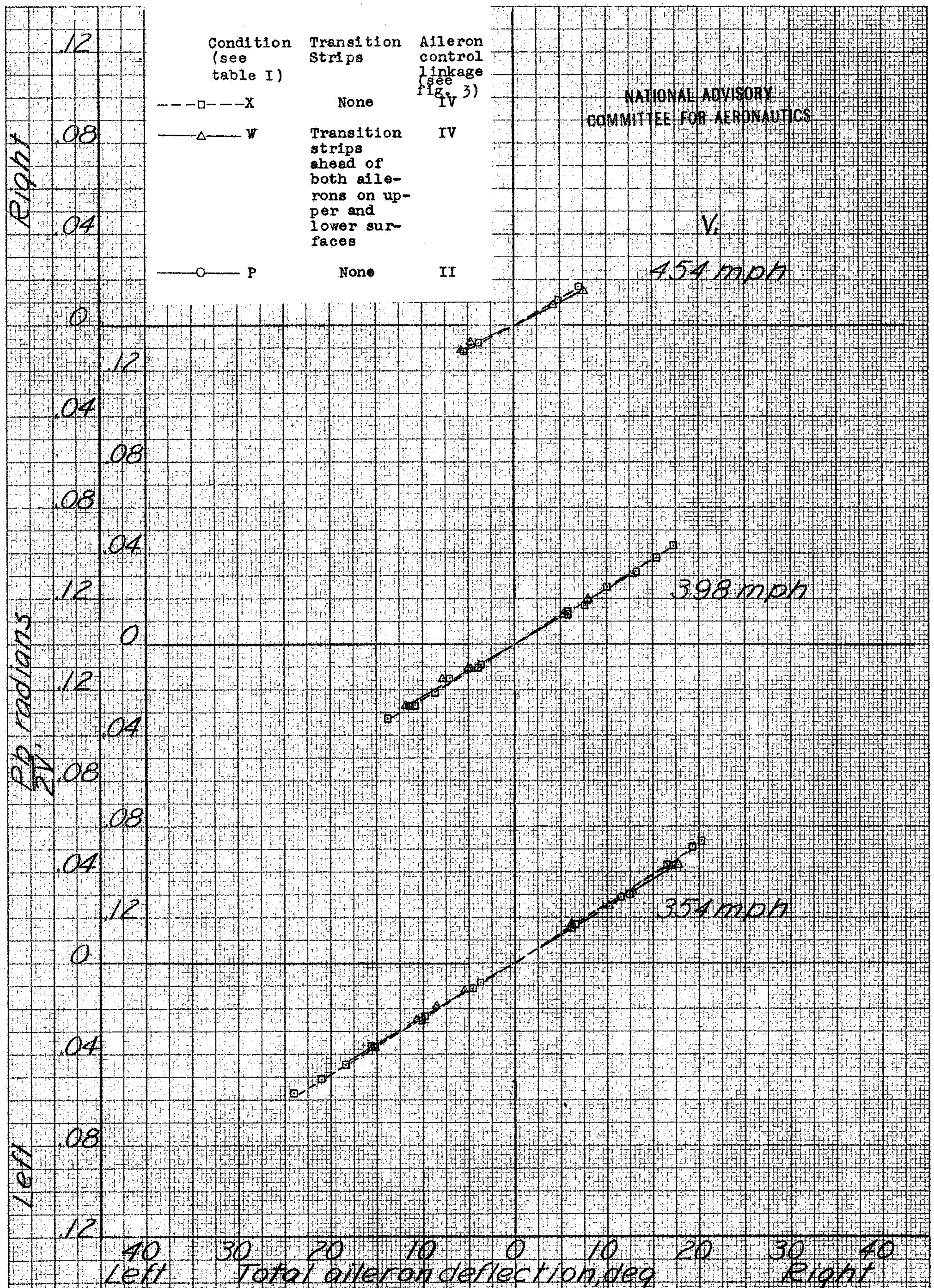


Figure 27.-Concluded.

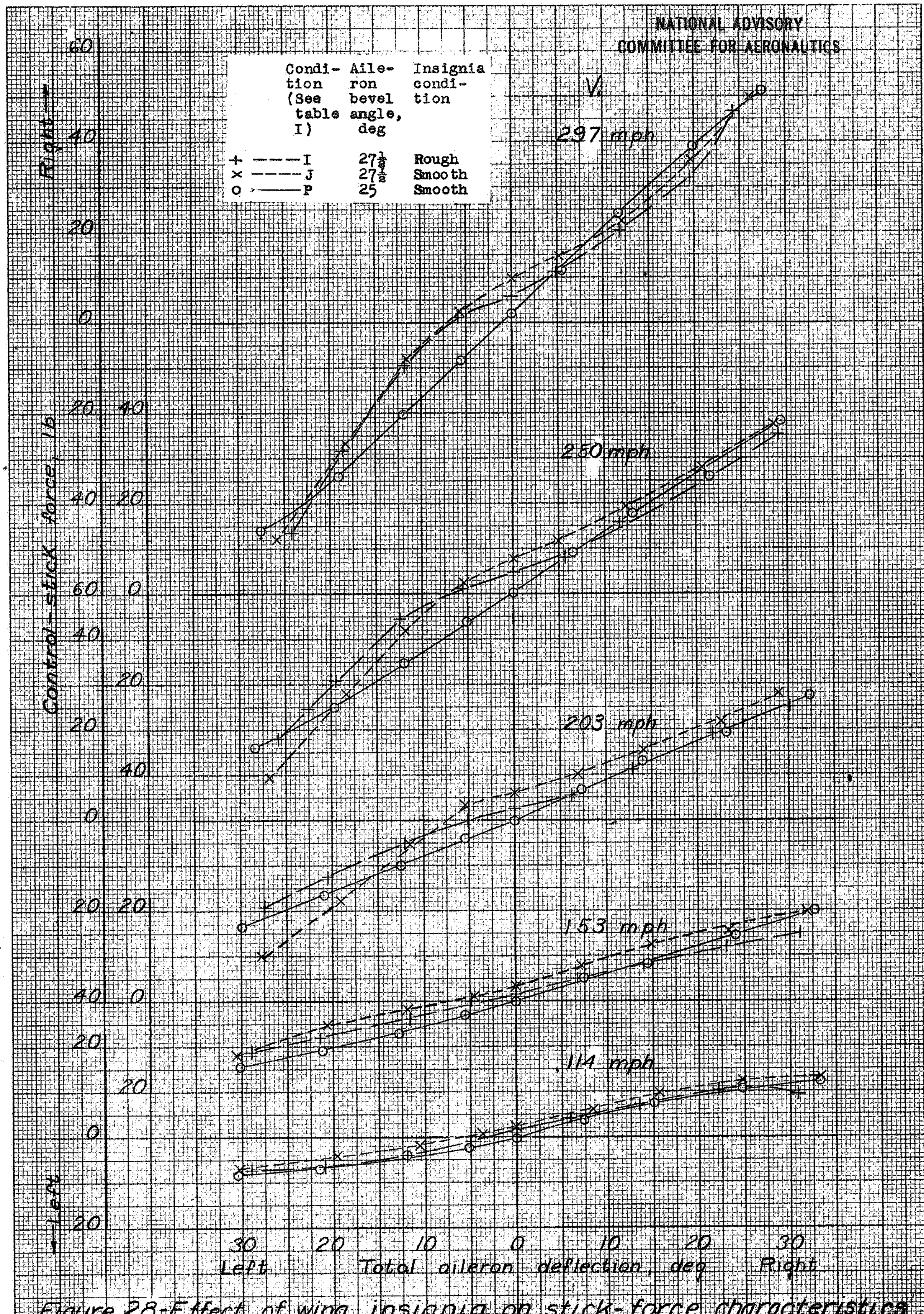


Figure 28.-Effect of wing insignia on stick-force characteristics of beveled trailing-edge ailerons North American XP-51 airplane

a

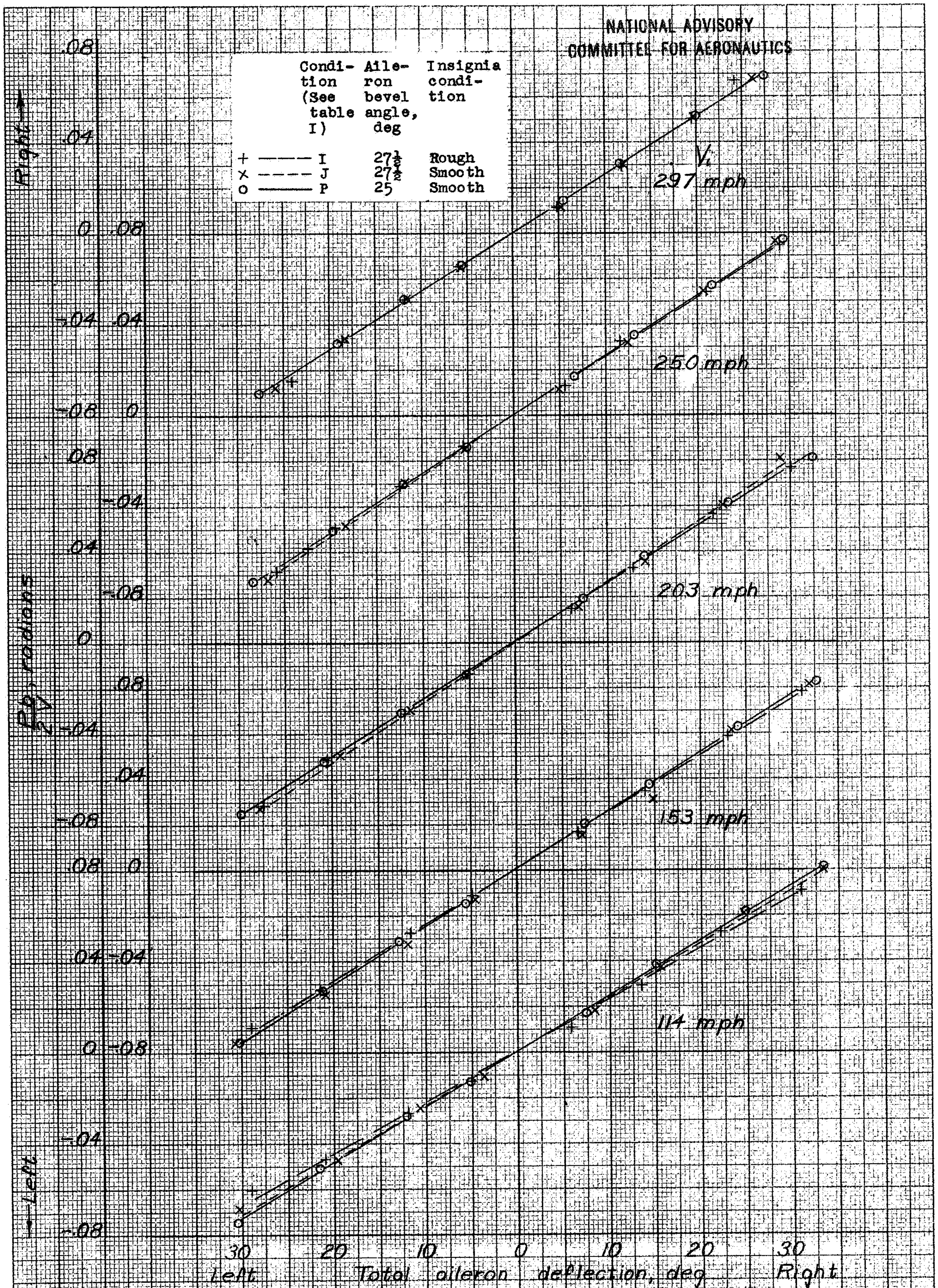


Figure 29.-Effect of wing insignia on effectiveness of beveled trailing-edge ailerons North American XP-51 airplane